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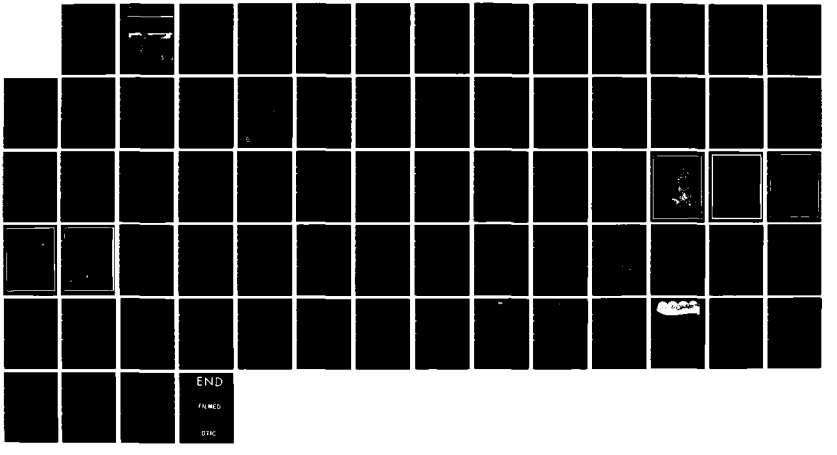
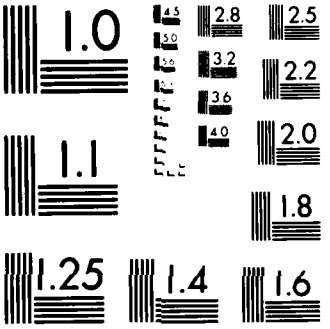
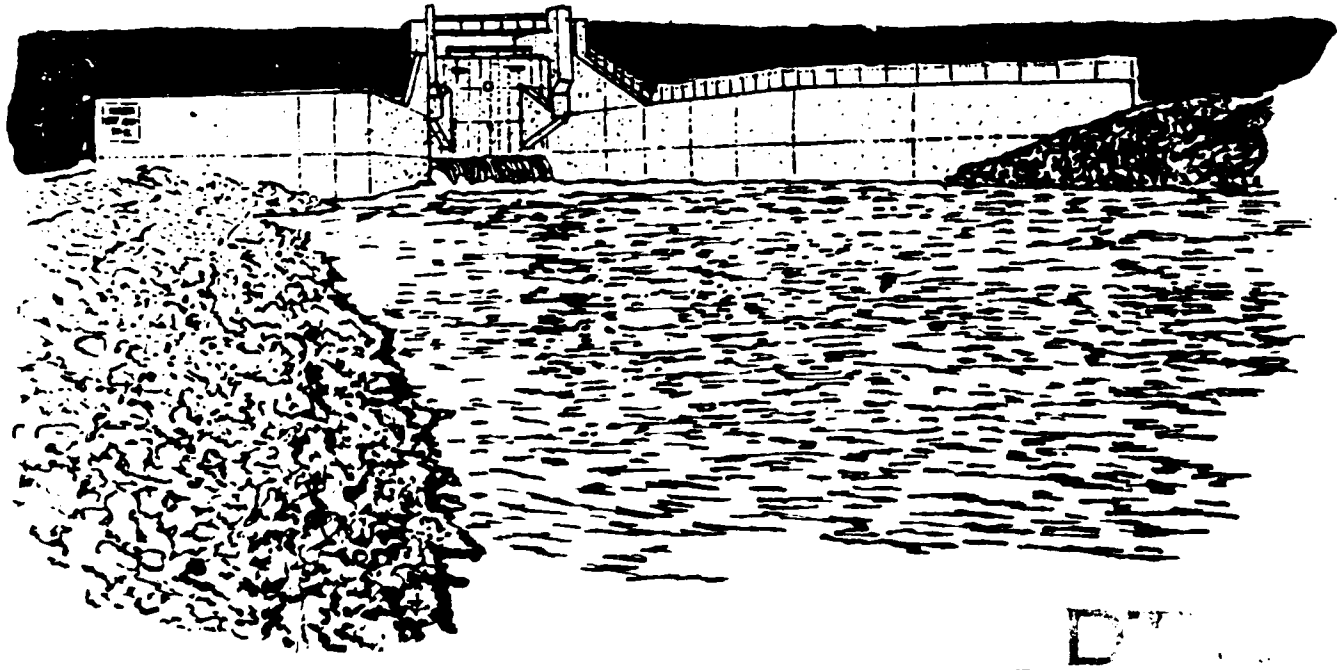




US Army Corps
of Engineers
St. Paul District

ORWELL RESERVOIR OPERATION PLAN EVALUATION



PROBLEM APPRAISAL REPORT

FEBRUARY 1985

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* ORWELL RESERVOIR OPERATION PLAN EVALUATION.		5. TYPE OF REPORT & PERIOD COVERED Problem Appraisal report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, St. Paul 1135 USPO & Custom House St. Paul, MN 55101-1479		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE February 1985 13. NUMBER OF PAGES 62 p.
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

RESERVOIRS
RED RIVER OF THE NORTH
DAMS

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report summarizes the problem identification information gathered during the initial stages of the St. Paul District Corps of Engineers Orwell Reservoir Operation Plan Evaluation (ROPE). Concerns about flood control, summer low flows on the Otter Tail and Red Rivers, sedimentation, fish and wildlife, recreation, shoreline erosion, hydropower, and cultural resources will be addressed in the remaining activities. Long-term water supply and water quality are outside the scope of this study. The ROPE study will be limited to considering an alternative operating plan in the project area.

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ORWELL ROPE

(RESERVOIR OPERATION PLAN EVALUATION)

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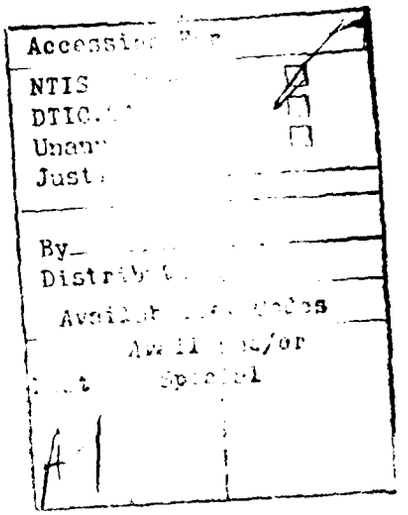

Department of the Army
St. Paul District, Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101-1479

February 1985

ORWELL ROPE
(RESERVOIR OPERATION PLAN EVALUATION)
PROBLEM APPRAISAL REPORT

EXECUTIVE SUMMARY

This problem appraisal report summarizes the problem identification information gathered during the initial stages of the St. Paul District Corps of Engineers Orwell Reservoir Operation Plan Evaluation (ROPE). Significant concerns were gathered through public involvement and in-house experiences with the project.

Concerns about flood control, summer low flows on the Otter Tail and Red Rivers, sedimentation, fish and wildlife, recreation, shoreline erosion, hydropower, and cultural resources will be addressed in the remaining activities. Long-term water supply and water quality problems for the Red River basin are outside the scope of this study and will not be considered further in the Orwell ROPE.

This problem appraisal report recommends that the Orwell ROPE be completed as described in this report. The draft ROPE report is scheduled to be completed in September 1985, and the update of the reservoir regulation manual is tentatively scheduled to be completed by the St. Paul District's Hydrology Section in fiscal year 1987.

ORWELL ROPE

(RESERVOIR OPERATION PLAN EVALUATION)

PROBLEM APPRAISAL REPORT

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ORWELL ROPE

(RESERVOIR OPERATION PLAN EVALUATION)

PROBLEM APPRAISAL REPORT

PROJECT AUTHORIZATION

The Orwell Dam is part of a comprehensive plan for the Red River of the North basin authorized by Flood Control Acts approved on June 30, 1948, and May 17, 1950. The portion of the 1948 act that authorizes this project follows:

> The comprehensive plan for flood control and other purposes in the Red River of the North drainage basin, North Dakota, South Dakota, and Minnesota as set forth in the report of the Chief of Engineers dated May 24, 1948, is approved and there is hereby authorized the sum of $2,000,000 for the partial accomplishment of that plan.

Supplemental authorization is in the 1950 act:

> In addition to previous authorizations, there is hereby authorized the completion of the plan approved in the Flood Control Act of June 30, 1948, in accordance with the report of the Chief of Engineers contained in House Document Numbered 185, 81st Congress, for the Red River of the North Basin, at an estimated cost of $8,000,000.

Construction of the dam began in May 1951, and operation began in spring 1953. A contract for additional recreation facilities was completed in August 1971.

No local cooperation is required for the Orwell Dam project, including operation and maintenance.

PROJECT DESCRIPTION

LOCATION

Orwell Dam is in westcentral Minnesota, about 190 miles northwest of St. Paul and about 6 miles southwest of Fergus Falls, Minnesota (see figure 1). The dam is on the Otter Tail River, 33 miles upstream of the point where the Otter Tail and Bois do Sioux Rivers combine to form the Red River of the North.

PRINCIPAL PROJECT FEATURES

The principal project features are the homogeneous rolled earth-fill embankment, combined spillway and outlet structure, and two low perimeter dikes.

Embankment and Dikes

The embankment and two dikes were designed and constructed using a homogeneous section. The embankment has a cutoff trench (10-foot maximum depth) to minimize seepage through the upper sand and gravel foundation layer. A 3-foot-thick horizontal drain (pervious drainage blanket) intercepts any through seepage and underseepage. Slope protection includes 12- and 18-inch riprap. The top has a 6-inch stabilized aggregate surfacing. The embankment crest length is 1,355 feet, and the maximum height from embankment crest to toe is 47 feet. Average height of the main embankment is 40 feet. The two dikes have a maximum height of 10 feet and a combined length of 1,140 feet. The embankment and structures are founded on glacial drift overlying bedrock. The maximum pool elevation (spillway design flood) of 1075 feet msl will develop a head of 35 feet on the downstream toe of the embankment.

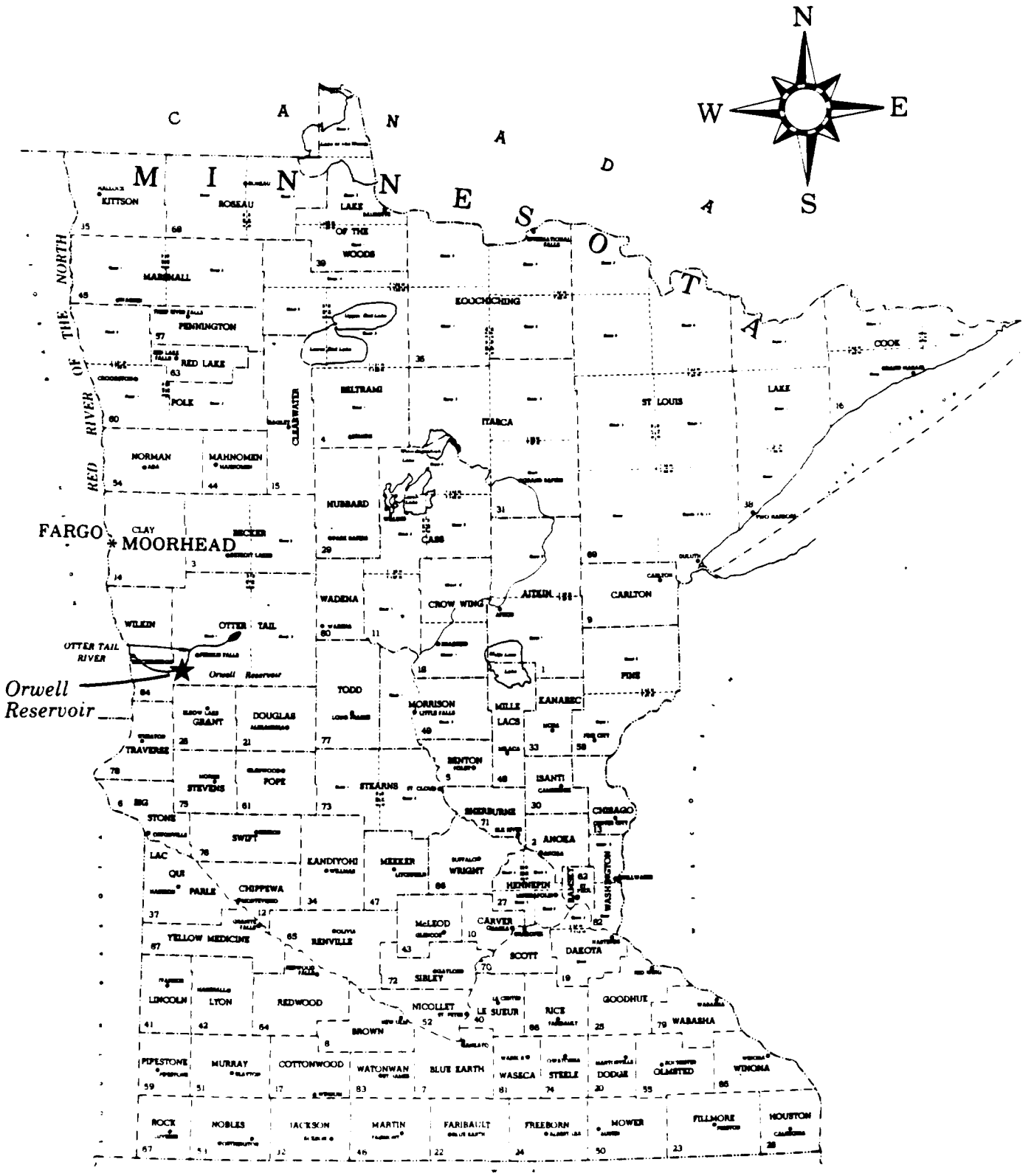
N
W
E
S
C A N A D A
M I N N E S O T A
NORTH DAKOTA
RED RIVER OF THE NORTH
FARGO
MOORHEAD
CLAY
OTTER TAIL RIVER
Orwell Reservoir
Orwell Reservoir
KITTSON
ROSEAU
LAKE OF THE WOODS
MARSHALL
PENNINGTON
RED LAKE
POLE
CLEARWATER
BELTRAMI
KOOCHICHING
ITASCA
ST LOUIS
LAKE
COOK
NORMAN
MAHNOMEN
HUBBARD
CASS
CROW WING
AITKIN
CARLTON
WILKIN
OTTER TAIL
WADENA
TODD
MORRISON
MILLE LACS
KANABEC
PINE
GRANT
DOUGLAS
TRAVERSE
STEVENS
POPE
STEARNS
BENTON
ISANTI
CHISAGO
BIG STONE
SWIFT
KANDIYOHI
MEEKER
WRIGHT
HENNEPIN
ANOKA
LAC QUI PARLE
CHIPPEWA
YELLOW MEDICINE
RENVILLE
McLEOD
CARVER
SCOTT
DAKOTA
LINCOLN
LYON
REDWOOD
SIBLEY
NICOLLET
LE SUEUR
RICE
GOODHUE
WABASHA
BROWN
PIPESTONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON

Figure 1

Embankment Foundation

The embankment is founded on a 2- to 10-foot-thick layer of pervious sand and gravel overlying a 6-1/2- to 40-foot-thick layer of cohesive soils consisting of lean clay, silty clay, clayey silt, and silt, with some sand and gravel lenses. These formations are underlain by fine to medium sands of undetermined depth. The groundwater table in the upper pervious sand and gravel layer was found at or near the ground surface when preconstruction borings were done at the damsite. The same borings revealed artesian water in the underlying sands with sufficient pressure to raise the water to the ground surface. Materials at both abutments are primarily 25 to 30 feet of lean clays with some lenses of sand and gravel overlying 15 to 30 feet of clayey silts and silts. Fine to medium sands of undetermined depth underlie the clay and silt materials. The spillway and outlet structure are founded on 19 feet of dense, inorganic silt, and 7-1/2 feet of clayey soil, the latter extending to the sand layer which is found at depths of 22 to 50 feet below the valley floor.

Spillway

The reinforced concrete spillway can be divided into five structural components: the upstream approach wingwalls, the ogee crest and abutment section, the trapezoidal chute, the trapezoidal stilling basin, and the downstream wingwalls. The ogee crest and abutment section is designed to act integrally as a rigid monolithic reinforced concrete gravity structure. Thickness of the ogee section varies from 9 to 17 feet, and wall thickness is 8 feet minimum at the top. Maximum wall height is 50 feet. The chute and stilling basin sections are also monolithic structures having floor slabs with integral walls, but are not designed as rigid structures. Floor width varies from 40 to 80 feet, and slab thickness varies from 4 to 6 feet, except for the transition to the ogee crest at the upstream end. The upstream approach and downstream wingwalls are inverted "T" cantilever retaining walls. Chute and stilling basin floor slab drainage is provided by a 6-inch

Corps of Engineers, should take the lead to provide the basin-wide perspective required to accomplish comprehensive planning. However, support and requests for the work would be needed from both States involved in the basin.

Irrigation - Long-term water supply for irrigation is complex and can have basin-wide consequences. Irrigation is interrelated with municipal and industrial water supplies. Thus, any basin-wide water supply planning effort should also consider present and projected irrigation demand. Without such a comprehensive water supply plan, it is impossible to determine the complete and long-term effect that Orwell Reservoir might have on irrigation requirements.

A very approximate assumption was made for considering the more short-term effects that the operation of Orwell might have on irrigation. The assumption is that any ground-water-based irrigation would have imperceivable effects or demands on Orwell Reservoir and its operation. However, if any irrigators have intakes directly in the reservoir, in the Otter Tail River downstream of the reservoir, or in the Red River upstream of Fargo-Moorhead, then their demand for water should be considered. More work is needed to inventory any such surface water irrigators and the existing institutional controls over them. Although the inventory is impossible to do within the resources of this study, it should be a part of any comprehensive water supply planning done for the entire Red River basin.

Urban Flood Control

Wahpeton, North Dakota, and Breckenridge, Minnesota, are located where the Otter Tail and Bois de Sioux Rivers join to form the Red River of the North. These two communities are the only urbanized areas that receive flood control benefits from operation of the Orwell Reservoir. The other communities in the study area are either too far from the Otter Tail River to be flooded by it or too far downstream on the Red River to receive benefits from operation of the Orwell Reservoir. The

Water Supply Sources

City	Red River	Sheyenne River	Groundwater
Breckenridge			X
Fargo	X	X	X
Moorhead	X		X
Wahpeton			X

The above table indicates that all four cities have systems in place to obtain ground water. In dry periods, the ground water systems should prove to be more dependable than the available surface water supplies, including Orwell Reservoir. Thus, the existing reservoir operation plan, including any possible modifications, would provide little relief during any sustained drought event. The four cities most affected by the Orwell project, listed on the table above, would have to depend on their ground water systems during a sustained drought.

Long-Term Problems - The recent Fargo-Moorhead urban study considered the long-term water supply and demand needs for municipal and industrial uses. During that study, information was gathered from a number of agencies concerned with water supply in the Red River basin. One problem, made quickly evident, was that no comprehensive effort was being made to coordinate sources with projected needs on a long-term and basin-wide basis. Also, there is an overall tendency by the individual water users to consider their water demand and supply for no more than several years in the future. The public contacts made for this problem appraisal report appear to support that tendency. Thus, it would be impossible to determine, within the scope of this study, how the operation of Orwell Reservoir would contribute to the long-term water needs of the Red River basin. Long-term and comprehensive water supply planning is probably needed for the Red River basin. Such planning should include water quality constraints and water conservation concepts. A HEC-3 computer model developed by the Corps during the Grand Forks-East Grand Forks urban study could be expanded and updated to be used as a tool for such comprehensive water supply planning. An agency, such as a coalition of the involved States, or possibly the

over a short period. Moorhead takes its water from the Red River whenever it is available at high enough quantity and quality. Otherwise, Moorhead pumps ground water that is more expensive to pump and usually more expensive to treat. Most of the communities along the Red River use similar water supply systems. Moorhead has not experienced winter flows that were too low, and would prefer the summer flows supplemented to flush algal blooms. Moorhead does little pumping in the winter; instead, does most of its pumping in the summer to satisfy peak demand.

Fargo indicated that their past operation has worked well in providing water supply to their community. That city would not like to see the Orwell Reservoir operation changed materially for water supply purposes. However, summer operation should be reviewed to provide better pollution abatement. Fargo also has an intake and pipeline to the Sheyenne River, but the city prefers the quality of the Red River water. The city is also concerned that the volume available in the Red River is used as a decision criteria by the North Dakota Health Department to limit the quantity of effluent from the Fargo waste water treatment plant. The city is not allowed to discharge effluent under the ice, so often it must store effluent until summer months. However, during the summer, the lower flows limit the amount of effluent allowed to be released.

The cities of Wahpeton, North Dakota, and Breckenridge, Minnesota, indicated that they no longer depend on river water for their main supply. Both cities have switched over to ground water systems for their primary source of municipal and industrial water. Breckenridge maintains their intake in the Otter Tail River for an emergency source of supply.

The following problem definition sections and the later planning objective statements were developed using the assumption that the project would be operated as though only that problem would be addressed. Using that assumption, the maximum possible contribution from the project can be determined for each problem or purpose. It is certain that no one potential reservoir operation plan can maximize benefits for all purposes at the same time. However, the net benefits of the overall project will be maximized, as required by Federal water resource laws. In order to maximize net benefits for the project, some of the project purposes will be reduced from their maximum potential benefit levels so that other purposes will provide greater net benefits. However, the tradeoff of benefits among purposes is also constrained by a relative priority of purposes as specified in the existing Congressional authority. The Minnesota Department of Natural Resources (MDNR) also have stated certain priorities among natural resource purposes. The MDNR priorities or stated priorities of other affected agencies will be used to the greatest practicable extent.

PROBLEM DEFINITION

Water Supply

Short-Term Problems - Water department representatives from the two cities of Fargo, North Dakota, and Moorhead, Minnesota, indicated concern about the quality of the water in the Red River. The Red River is the main water supply source for both cities. During a telephone conversation, the Water Department representative from Moorhead indicated that the recent (December-January) large releases from Lake Traverse had caused them to expend $80,000 over budget for chemicals for water treatment. He suggested that the higher quality water from Orwell Reservoir be used to dilute releases from Lake Traverse on the Bois de Sioux River. Lake Traverse is also a Corps-operated reservoir. Another suggestion is that smaller, more gradual Lake Traverse releases should be made over a long period of time, rather than large, quicker releases

PUBLIC INVOLVEMENT FOR ROPE

During the problem definition period of the study, the goals of the public involvement effort were to: (1) inform the affected public of the study, (2) actively seek their input into defining problems, needs, and opportunities relating to operation of Orwell Reservoir, and (3) develop a complete list of interested parties, both governmental and private, for coordination of the study activities. To accomplish these goals, a study initiation notice was mailed to about 165 offices and interested individuals. In addition to written and oral comments received in response to the notice, key agencies were contacted by telephone to request active participation, and two briefings were held in the Twin Cities area. Copies of a number of correspondence items are contained in an appendix to this problem appraisal report.

To initiate the alternative formulation portion of the study, a notice will be sent to the expanded mailing list, summarizing the problems defined in this report. As formulation and problem refinement progresses, additional notices may be sent or additional meetings may be held, if appropriate. A final public notice will be mailed to the expanded mailing list with a summary of study conclusions and the District Engineer's recommendations.

PROBLEMS, NEEDS, AND OPPORTUNITIES

INTRODUCTION

The following problem definition paragraphs contain preliminary information concerning the significant resources involved with the Orwell Reservoir and its operation. The information was obtained from the various public agencies or groups or in-house experts concerned with the particular resource. This information should become more refined as the study activities progress and as the public involvement program is accomplished. Accurate problem definition provides a necessary basis for formulation of alternative operation plans for Orwell Reservoir.

Summary of Contracts and O&M Costs

Fiscal Year	Contract Work	Contract Amount	O&M Cost
1951	Construction of Orwell Dam	$1,183,941*	$ -
1952	Reservoir clearing	36,198*	-
	Dam tenders bldg. and service bldgs.	31,694*	
1953	Utility line relocations	3,703*	8,648
	SAR #2 road	30,141*	
	Emergency bulkheads	57,400*	
1954	Reservoir fencing	1,724*	17,549
1955	Recorder house	400	10,322
1956	-	-	16,171
1957	Tainter gate housing	18,900	35,977
1958	-	-	21,102
1959	-	-	13,882
1960	-	-	13,951
1961	-	-	15,720
1962	-	-	15,377
1963	-	-	17,806
1964	-	-	25,562
1965	-	-	31,917
1966	Rubber seals	3,300	20,024
1967	-	-	27,933
1968	-	-	27,594
1969	-	-	39,392
1970	-	-	30,798
1971	-	-	48,542
1972	Plans and specs. for road	4,639	42,232
	Recreation facilities	13,407	
1973	Plans and specs. for road	8,278	70,043
	Ditch excavation	9,390	
1974	New road below dam	58,405	110,817
1975	-	-	76,006
1976	Seepage repair	19,958	260,184
	Sanitary facilities	27,182	
1977	Repair earth dam	67,854	181,576
1978	Water quality	5,400	172,493
	Test well	22,240	
1979	Maintenance building	69,000	260,164
	Relief wells	105,286	
1980	Maintenance building	59,125	222,273
	Dam maintenance	38,547	
1981	Hydrologic analysis	15,500	164,830
	Cultural resources	14,580	
1982	Hydrologic analysis	16,309	159,738
	Cultural resources	2,981	
1984	Sandblast and paint tainter gate		50,000

* Not included in O&M cost.

HISTORY OF MAINTENANCE AND OPERATIONS

CHRONOLOGY OF EXPENDITURES

The table on the following page lists contract expenditures, by fiscal year, for the 30 years the dam has been in operation. Total operation and maintenance costs are also listed.

REHABILITATION ACTIVITIES

The following paragraphs briefly describe previous major rehabilitation activities.

1976 Seepage Repair

Artesian pressures first became a cause for concern during the 1970 periodic inspection. At that time, a general wet condition was noted along the downstream toe. Clearing was recommended, along with construction of a drainage ditch and the installation of piezometers. This work, performed in 1973, was only partially effective. In 1976, a 15-inch perforated PVC toe drain was installed, and a 150-foot-wide berm, up to about 5 feet deep, was then constructed along the entire dam toe adjacent to the existing road. The berm was extended to 250 feet over the old river channel area along the right abutment.

1977 Earth Dam Repair

In May 1977, boils of significant size with some displacement of material (sand cones) were detected in the bottom of the spillway discharge channel. To relieve the pressure and provide adequate safety, relief wells were installed along the right channel bank in 1979.

two 4-foot conduits would be required to meet low-flow requirements and current design criteria.

Stilling Basin

A preliminary hydraulic analysis done in 1979 indicated a potential for scour downstream of the stilling basin under certain tailwater conditions. Although no modifications are scheduled at this time, the stilling basin design may be reviewed at a future date.

Periodic inspections of the stilling basin require dewatering of the basin. The existing two low-flow conduits and the tainter gate discharge into the stilling basin and can not be used during inspections. Some means of providing a continuous discharge to the river downstream of the dam during the inspections is needed.

Shoreline Erosion

A considerable amount of shore erosion has occurred since Orwell Lake was first impounded. A number of solutions have been identified. Apparently, the best solution would be to lower the maximum pool level to 1067.9 feet msl or at least to minimize the amount of time the pool is held at/above that elevation.

Lack of Vegetation on Shoreline

Much of the Orwell Reservoir shoreline and adjacent project lands suffer from a lack of vegetation as a result of the active erosion problem. Burdock or similar sparse weeds are the only vegetation that appear to survive on the eroding portions of the shoreline. If the shoreline erosion problem is addressed, the vegetation problem might also be considered and incorporated as part of the solution to shoreline erosion.

CURRENT ORWELL PROJECT CONDITION

A number of the project features have had problems corrected but a number of problems remain. The following paragraphs describe the problems that have not been corrected.

Emergency Spillway Capacity

The project has several problems with the features available to release stored water from the reservoir. The recent National Dam Safety Study indicated that Orwell Reservoir should have additional emergency spillway capacity for an extremely rare and large flood event, such as the probable maximum flood. A separate study for emergency spillway capacity is scheduled to be completed in spring 1985. The design will probably include an uncontrolled overflow type spillway located away from the existing tainter gate site.

Low And Normal Flow Controls

The two existing 24-inch low-flow conduits and the single large tainter gate have operation problems. The two low-flow conduits can only operate fully open or fully closed. The present double disc type valve vibrates and cause excessive wear when left partly open. The tainter gate is used to control low-flow releases for those conditions when partially open valves would normally be used. However, because of its large size, the tainter gate is not an adequate substitute for the low-flow valves. Vibration and erosion of the tainter gate lip can occur during very small gate openings. Complete replacement of the double disc valves would require excavation of substantial amounts of surrounding concrete. An alternative style valve, such as a butterfly or knife valve, could be installed to allow the low-flow conduits to operate over their entire range. Replacement of the valves may not be enough to meet the minimum required discharge at all pool elevations. At lower pool levels, there is not enough hydraulic head to force the minimum allowable release through the conduits. It is estimated that

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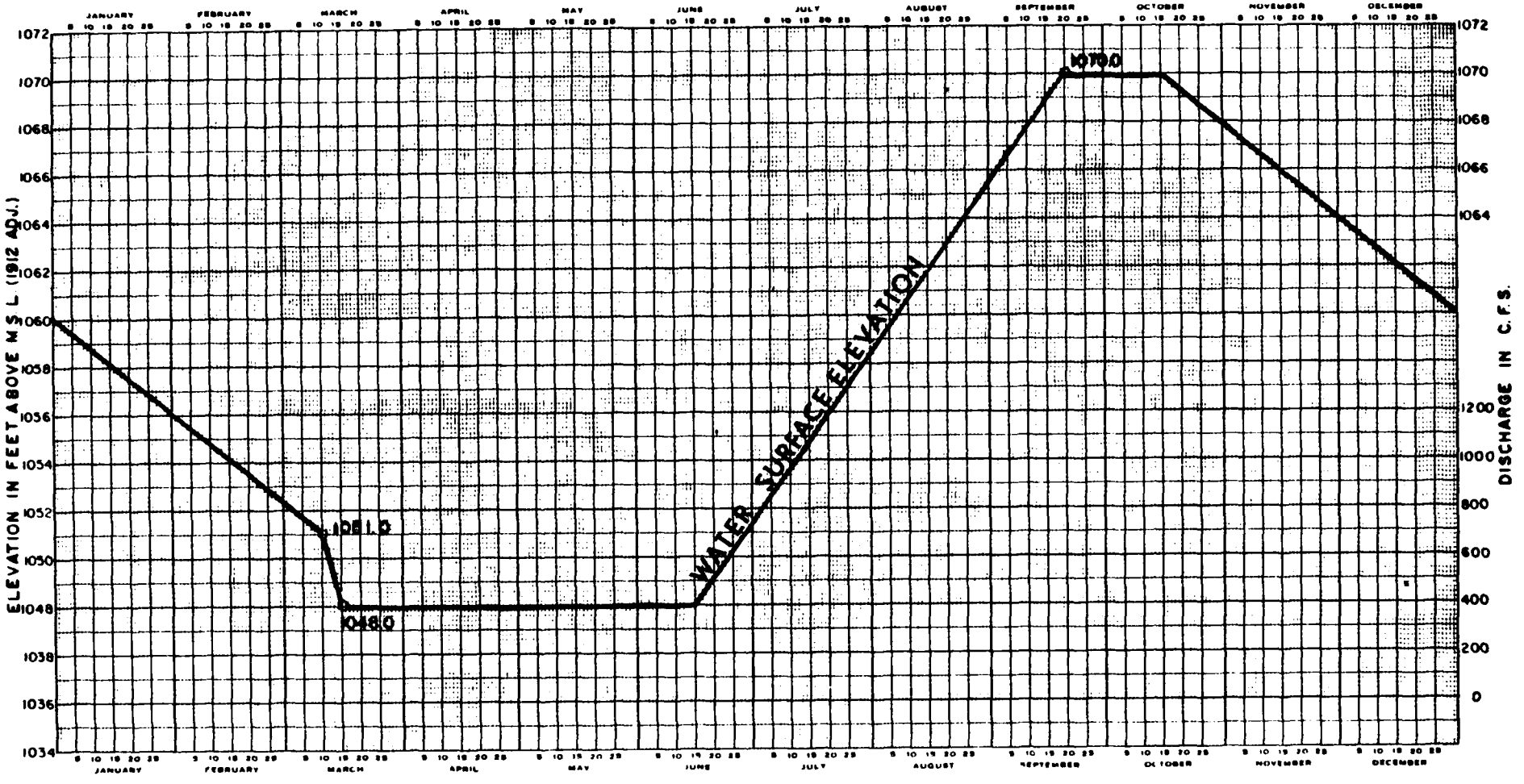
RULE CURVE

ORWELL DAM OPERATION PLAN



Regulation Schedule - Orwell Dam and Reservoir

Regulation Schedule	Stage	Condition	Operations
Routine Operation			
Freezeup to breakup	1070.0 to 1048.0	Normal	Beginning November 1 (freezeup), schedule winter releases to assure drawdown to elevation 1048.0, if necessary, by April 1. Coordinate with water requirements for sugar beet processing.
Breakup to about June 15	1048.0 to 1070.0	Normal runoff	During runoff period, allow reservoir to fill to elevation 1070.0. Discharge to bank-full capacity (900 cfs). Lower to 1048.0, if necessary. (See schedule plates 13 and 13A.) Do not aggravate flooding downstream.
June 15 to about September 20	1048.0 to 1070.0 or to elevation indicated by Reservoir Operator Curves, then fill to 1070.0.	Normal	Fill to elevation 1070.0 by September 20 in accordance with the Inflow-Recession and Flow Storage Filling Schedule Curves as shown on Plates 13 and 13A. If excess runoff occurs during period, fill to 1070 prior to September 20, if necessary. Maximum discharge will be bank-full capacity (900 cfs). After crest has been reached, revert to schedule prescribed above.
September 20 through December	1070.0-minus	Normal	Beginning about September 20 through December, release discharge for water supply, pollution abatement, and sugar beet processing. Minimum requirements, approximately 40 cfs.
Flood Control			
High water period	1048.0 to 1070.0+	Large runoff predicted	Fill to 1070.0 but when it becomes apparent prior to filling to elevation 1070.0 that induced surcharge will be necessary, discharge greater than bank-full capacity (presently 900 cfs) can be released to permit a more gradual increase in discharges after elevation 1070.0 is reached.
Induced surcharge	1070.0+	Pool continues to rise above 1070.0	Discharge 90 percent of reservoir inflow rate for previous 3-hour period. After maximum pool has been reached, maintain maximum gate opening until pool level drops to 1070.0.
Induced surcharge	1070.0-	Pool falling	When pool drops to 1070.0 revert to appropriate routine operation schedule.
Water Supply and Conservation*			
Low water period	1070.0 to 1048.0		Storage will be released if available to supply minimum requirements downstream. Minimum releases will not be less than 5 second-feet. Raising reservoir level to 1070.0 by September 20 may not be possible.

* Requirements for water supply and pollution abatement for the cities of Fargo, North Dakota, and Moorhead, Minnesota, must be supplied by Orwell Reservoir until such time as the proposed Fargo Diversion Channel has been constructed.

OTTER TAIL BASIN DESCRIPTION

The Otter Tail River rises west of Fergus Falls, Minnesota. The river flows south through a series of lakes until it reaches Otter Tail Lake, where it turns and flows west to its confluence with the Bois de Sioux River at Wahpeton. The basin contains more than 1,100 lakes, covering more than 15 percent of the total basin area. An additional 6 percent of the basin is covered by swamps and marshes. The average slope of the river from Orwell Dam to Breckenridge is 3 feet per mile. Approximately 90 percent of the basin is used for agriculture including grain crops (primarily wheat and corn) and livestock. Orwell Reservoir is located at the edge of the former bed of glacial Lake Agassiz, in the transition zone composed of former beach ridges between the upland and lowland plains.

EXISTING PROJECT OPERATION AND RULE CURVE

Purpose of Operation

The primary objective in the operation of Orwell Reservoir is the reduction of damages caused by flooding in the lower reaches of the Otter Tail River, especially at Wahpeton, North Dakota, and Breckenridge, Minnesota. Also, at times of deficient flow in the Red River, the water in storage in this reservoir may be used to supplement natural flows for water supply and pollution abatement. In addition to these primary objectives, the reservoir shall be used to assist in fish and wildlife conservation whenever possible.

Regulation Schedule

The following table contains general information about how the Orwell project is operated during routine flood control and low-flow conditions. The information is displayed graphically as a rule curve on page 9.

21.1. The design discharge is 900 cubic feet per second (cfs), and the reservoir operators use that figure as the maximum release discharge to prevent induced flood damage. The channel modification has a design bottom width of 30 feet between miles 21.1 and 16.0, and a 50-foot bottom width between miles 16.0 and 9.7. The material removed from the channel was placed in banks along the river no more than 8 feet high, and these banks are discontinuous at intersections with the old channel or natural watercourses to provide side drainage into the channel. The St. Paul District completed an operation and maintenance manual for the project in April 1960. The local sponsor and contact for the project is the Wilkin County Drainage and Conservancy District No. 1, located at Breckenridge, Minnesota. The channel capacity will be checked because it is suspected that the actual figure is greater than the 900 cfs presently being used by the St. Paul District Water Control Office.

Project Lands

The Federal Government owns about 1,985 acres of land in connection with the project (to about elevation 1073 feet msl). About 1,870 acres are leased to the Minnesota Department of Natural Resources for wildlife management. Recreational opportunities at Orwell Reservoir are oriented toward sightseeing and nature study.

Recreation

Day-use recreation facilities are located at the damsite. Hunting (waterfowl, white-tail deer, pheasant, partridge, and fox), sightseeing, nature study, and picnicking are among recreational opportunities available at the project. Road access and parking are provided near the dam. Some canoeing and inner-tube rafting occurs on the Otter Tail River downstream from Orwell Dam.

gravel blanket under the slab and a system of 4-inch screened floor drain weepholes. Drainage for the wall section is provided by pervious backfill with filter gravel surrounding a perforated 8-inch V.C.P. drain system that discharges through the chute and stilling basin walls.

Tainter Gates

Spillway discharges are controlled by the single 33-foot-long and 27-1/2-foot-high welded structural carbon steel tainter gate. The tainter gate is electrically operated by means of duplicate, independent driving units on each abutment wall. An emergency generating unit provides power in the event of commercial power failure. A nine-section emergency bulkhead and a pickup boom are provided for emergency closure of the spillway. The bulkheads are fabricated of aluminum alloy to permit handling and installation by truck crane.

A potentially serious condition that developed during the first winter of operation involved an icing problem that froze the tainter gate in a partially opened position and resulted in loss of reservoir regulation. The condition was corrected in 1957 by installing a corrugated aluminum tainter gate housing connected to two L.P. gas-fired, forced hot-air heating systems.

Low-Flow Conduits

There are two 24-inch CMP gated low-flow conduits in the ogee crest abutments. Flow through these conduits is controlled by 24-inch double-disk gate valves with inverts at elevation 1040.0 feet msl. Bulkhead recesses are provided in the intakes to the gate valves for emergency closure.

Downstream Channel

In 1954 and 1955, the Otter Tail River channel was cleaned, enlarged, and straightened by the Corps of Engineers between river miles 9.7 and

Federal Flood Insurance Administration prepared a flood insurance report, in March 1978, for Wilkin County, Minnesota, that includes the Breckenridge area. The report includes flood profiles (500-, 100-, 50-, and 10-year profiles) for the Otter Tail River from its mouth to river mile 25. Those profiles cover both cities to a sufficient level of detail for this study. The profiles also cover the flood-prone agricultural areas discussed in the next section of this report. Another flood insurance report, for Wahpeton, North Dakota, is nearly complete and should provide additional hydrologic information.

As part of this study, an inventory of flood-prone property will be assembled for Wahpeton and Breckenridge. The flood profile information and property inventory will be combined to indicate the approximate flood elevation-damage relationship for the two communities. The discharge-frequency information for the Otter Tail River will be updated and combined with the elevation-damage curves to produce flood damage-frequency relationships for with and without the Orwell project. This will provide an approximate dollar estimate of the urban flood damage reduction provided by the Orwell Reservoir. With the updated information, it can be determined whether changes to the Orwell operating plan could provide additional urban flood damage reduction for Wahpeton or Breckenridge. It is also possible that the overall project may provide maximized net benefits by trading off some of the flood control benefits for greater benefits from another purpose. Potential trade offs will be evaluated and properly coordinated as required by Federal water resource guidelines. See the evaluation section for further information.

In a January 1985 letter, the city of Wahpeton expressed concern about the effect that Orwell Reservoir operation may have during flood times for the city. Wahpeton's flood-prone areas are nearly all public property, and the city has constructed a levee system for those areas. It is suspected that the Otter Tail River presents a greater flood threat to both communities than the Bois de Sioux River. This threat should be more evident after the Otter Tail River hydrologic information

if reviewed. Lake Traverse should provide a greater percentage of control over the Bois de Sioux flood flows than Orwell has over the Otter Tail because Traverse has about 10 times the flood storage capacity of Orwell Reservoir. In fact, the natural lakes in the Otter Tail basin probably provide significantly more flood storage than the flood storage available in Orwell Reservoir. These factors will be reviewed and additional, more detailed flood control studies may be warranted beyond the scope of this study.

Agriculture Flood Damage Reduction

Agricultural flood damages occur downstream from Orwell Dam in the Otter Tail River floodplain in an area of about 38,000 acres. The flood-prone area is generally located between river miles 9.7 and 24.8, and mainly south of the Otter Tail River. The St. Paul District has obtained 1980 land-use data for that flood-prone area from the Minnesota Land Management Information Center (LMIC). The land-use information is stored by LMIC in a computer data base set up into 3-1/2-acre grid cells that show the crop types or other land uses in each grid cell. Average elevations are also available for each grid cell so that flooded areas can be identified for given flood profiles. An available flood insurance study has the flood profiles for the 500-, 100-, 50-, and 10-year floods. Thus, a damage-discharge curve can be produced for agricultural damage. After the discharge-frequency curve is reviewed in spring 1985, a damage-frequency curve can be produced for the with-project and without-project conditions. This proposed evaluation will provide an approximate indication of dollars of agricultural flood damage reduction provided by the existing project operation. The original project was designed to provide protection up to the 10-year flood. The operation of the project will be reviewed to determine whether additional agricultural flood damage reduction might be provided by a modified operating plan or improvement of the existing channelization project. The condition of the existing Otter Tail River channelization project, built by the Corps in 1954, and the remaining natural channel will also be reviewed. The channelization project works

together with Orwell Reservoir operation to reduce agricultural flood damages.

Pollution Abatement and Water Quality

Pollution abatement is an authorized purpose of the Orwell project. Presently, the reservoir is filled from mid-June to early September. The stored water is released for pollution abatement or dilution purposes beginning in late fall and throughout the winter. That means the reservoir is storing river flows during the season that the downstream communities state that they would like to have river flows supplemented. The reason that the river flows are presently stored at that time is that . . . at the time the project was formulated in the late 1940's, a substantial amount of untreated effluent was being released into the Red River. During the fall and winter, large amounts of untreated effluent were released from sugar beet processing plants. The natural fall and winter flows were supplemented with discharges from the Orwell Reservoir to dilute the waste-water effluent from sugar beet processing and other sources. Since the 1940's, water quality laws have been passed that require these effluents to be treated to higher quality standards. Thus, the large pollution abatement or dilution releases are no longer required during the fall and winter.

Pollution abatement was identified as a current concern by the municipal and industrial water supply interests of Fargo and Moorhead. Wahpeton and Breckenridge also mentioned concern about summer low-flow periods and the related aesthetic problems, although the cities no longer rely on the river for water supply. All four cities mentioned that during summer low-flow periods, Otter Tail and Red River flows should be supplemented from Orwell Reservoir or from the overall Otter Tail basin for the following reasons:

1. To help flush algal blooms in the Red River.
2. To dilute releases from Lake Traverse when those releases are of the poorest quality.

3. To allow for larger releases of wastewater treatment plant effluent.
4. To improve aesthetic appeal of areas near the Red River.

Water quality was also indirectly identified as a concern or as a constraint for many of the other purposes being considered. For example, water quality is important for water-contact activities such as swimming and canoeing. Water quality is an important aspect for fish and wildlife programs in the reservoir or the Otter Tail River.

Baseline water quality data will be gathered for project-related locations. A literature search is needed to compile a bibliography of existing water quality data and ongoing monitoring activities of others. Additional analysis, such as numeric modeling of reservoir stratification may be needed for fisheries evaluation.

Shoreline Erosion

A considerable amount of shore erosion has occurred since Orwell Lake was first impounded. Steep banks have developed on about 35 percent of the high water shoreline of the main lake; many of the banks are nearly vertical. Erosion has apparently progressed to outside project lands in one area and a land exchange is being considered to correct that problem.

A report entitled Shoreline Erosion Process, Orwell Lake, Minnesota, by John R. Reid, University of North Dakota, was prepared in January 1983. That 2-1/2-year study was conducted to determine the causes of bank erosion in the lake and ways to slow its rate and magnitude. The report identified wave action accompanying high pool levels and, to a lesser extent, freeze-thaw and rainfall as the primary processes of erosion. The report recommended lowering the normal full pool from 1070 to 1067.9 msl and vegetating the slopes that would require some grading of the existing slopes. The effects of bank erosion on storage capacity and the useful life of the reservoir is being reviewed during this operating plan evaluation.

Part of the typical monitoring program accomplished for Corps reservoirs includes siltation ranges taken on a regular basis. There were 24 siltation ranges established in 1955, and repeat soundings have been taken at the same ranges in January 1964 and in January 1985. Preliminary results from the 1985 field work indicate that most of the change has been occurring at the shoreline. Material appears to be eroding away from the shoreline areas, but where that material is being deposited is not readily apparent. A few of the ranges indicate that up to a foot of material has been deposited in scattered bottom areas. It is not certain yet whether the volumes of lost/gained material balance out. More detailed evaluation will be accomplished and the results published in the Orwell ROPE report scheduled for September 1985.

Wildlife Resources

In December 1984, St. Paul District representatives met with representatives of the Minnesota Department of Natural Resources (MDNR) to discuss their concerns and suggestions for Orwell Reservoir. The area fisheries and wildlife managers were present. They discussed many of the following concerns and ideas to increase productivity. Other MDNR representatives discussed concerns about recreation and instream requirements for the Otter Tail River downstream of the reservoir. We addressed each concern in the appropriate section of this report. Many of the MDNR concerns and recommendations for Orwell Reservoir and the downstream reaches of Otter Tail River are documented in a 1982 inventory of resources of the Otter Tail basin. MDNR also sent a letter dated February 15, 1985, that lists specific problems, constraints, and opportunities for the specific Orwell project area. A copy of the letter is included in an appendix to this problem appraisal report after the conclusions and recommendations section.

The Orwell Wildlife Management Area (OWMA) is managed primarily for pheasant and waterfowl. Some benefits accrue to white-tailed deer and nongame species as a result of this management. Orwell Reservoir is

used as a resting and staging area for migrating waterfowl, including geese.

Existing reservoir operations do not have any appreciable effect on the management of the upland areas of the OWMA. More substantial effects take place on the wetland areas, especially those in the south arm of the reservoir. Fluctuating water levels inhibit the establishment of permanent aquatic vegetation in some of these wetlands. Raising water levels during the early summer months can flood waterfowl and game bird nests. Fluctuating water levels can strand waterfowl broods and limits use of the reservoir and the OWMA by furbearers such as muskrat and beaver. Lack of permanent vegetation and suitable denning sites are factors hindering use by furbearers.

Winter drawdowns can freeze out or strand furbearers. These drawdowns also eliminate water in certain areas that are important for spring waterfowl courtship activities.

One project feature with significant potential for improving the Orwell Reservoir and the OWMA for wildlife would be to create subimpoundments in the south arm of the reservoir. Creation of the subimpoundments would allow for the management of water levels in these areas for the maximum benefit of waterfowl.

Within Orwell Reservoir, proper stabilization of the pool would be a major factor in improving wildlife habitat. The pool should be regulated to control annual fluctuations to less than 2 feet. This would create stable riparian and shallow water habitats for both furbearers and waterfowl. Stabilization of the pool and subsequent establishment of aquatic plant growth would provide an additional food source for migrating waterfowl. The adverse impacts of winter drawdown would also be avoided.

Fisheries

Orwell Reservoir - The existing fishery in Orwell Reservoir consists primarily of rough fish such as carp and bullheads. Some game and panfish species, such as walleye, northern pike, and crappie, are present in low numbers.

The major problem for the fishery in Orwell Reservoir is the wide annual fluctuation in pool elevations (approximately 22 feet). The annual fluctuation has precluded development of a littoral zone with aquatic plants. Macroinvertebrate colonization of these areas is severely hindered. Aquatic plant beds are important for most game fish and panfish as spawning and/or nursery areas and for food and cover. Macroinvertebrates are important components of most aquatic flood chains.

The reservoir fluctuations hinder fish spawning and impacts on the survivability of fry and fingerlings.

The reservoir fluctuations contribute to bank erosion which in turn increases turbidity and siltation in the reservoir. Siltation covers hard substrates such as sand, gravel, and rock which are important for certain desirable sport fish. Turbidity reduces primary production and generally favors the success of rough fish over sport fish due to morphological and behavorial adaptations.

The optimum condition for the fishery in Orwell Reservoir would be to stabilize the reservoir pool. The optimum level would likely be in the range of 1065 to 1067 msl to maximize the available "living space" while reducing bank erosion. Stabilization of the pool would allow development of a littoral zone with aquatic plants. Wave action at a stable elevation may wash away some of the silts in the shallow areas, exposing harder substrates such as sands and gravels. Exposure of such substrates, in turn, could enhance spawning opportunities for species such as walleye and the sunfishes.

Otter Tail River Below Orwell Dam - The Otter Tail River below Orwell Dam is a low-gradient river flowing through a lowland plain where the predominant land use is for agriculture. The best fish habitat in this 40-mile reach is below Orwell Dam with habitat quality generally decreasing downstream toward the river's mouth. The fishery is dominated by redhorse, suckers, and carp. The most abundant game fish is the walleye, which is found most commonly in the tailwaters of Orwell Dam.

Currently, Orwell Reservoir operation affects the Otter Tail River primarily in two ways, by the annual pattern of releases and by the short-term changes in the rate of release. The annual operating plan calls for holding water over the summer for low-flow augmentation beginning in the fall (mid-September). In years of less than average precipitation, this plan can result in low flows in late summer that are less than optimal for the downstream fishery.

The opportunity exists to benefit the downstream fishery in the Otter Tail River through some modification of the reservoir operating plan. In most years, sufficient water appears to be available in the reservoir to insure minimum year-round flows in the range of 100 to 200 cfs. Releasing these flows in late summer of dry years rather than storing the water in the reservoir would benefit the downstream fishery.

High flows can also have adverse impacts on the river fishery. However, due to the physical limits of the reservoir, there would be less opportunity to moderate damaging high flows.

Fluctuations in discharge rates can adversely affect fish spawning, fry and fingerling survival, and macroinvertebrate production.

At times when discharges are decreasing, the daily rate of change in the discharge has been sufficient to strand fish and mussels in downstream areas. It would be beneficial to downstream aquatic resources to

minimize the rate of change in discharge, especially when reducing flows.

Otter Tail River Above Orwell Reservoir and Below Dayton Hollow Dam - The amount of "river" between Orwell Reservoir and the Dayton Hollow Dam ranges from 0.5 mile to 2.0 miles, depending on pool levels in Orwell Reservoir. The fishery in this reach of the Otter Tail River is dominated by carp, redhorse, and suckers. Walleye appears to be the most common game fish, with northern pike, largemouth bass, and crappie also present.

The largest impact of Orwell keservoir operation on this portion of the Otter Tail River is annual inundaton of the river by the reservoir pool. At full pool (1070 feet msl), much of the river up to the Dayton Hollow Dam tailwaters becomes inundated. This inundation probably does not have a significant impact upon the existing fishery. However, it likely hinders to some extent the success of species more adapted to riverine conditions, such as the redhorse, suckers, and walleye.

Improvement of the fishery in Orwell Reservoir would probably go a long way toward improving the sport fishing opportunities in this reach of the Otter Tail River. Species such as walleye would migrate out of the reservoir up to the Dayton Hollow tailwaters, enhancing the fishing opportunities there.

Stabilization of the reservoir pool would do the most to improve the reservoir fishery. Stabilizing the reservoir at a lower level would increase the length of river left in a flowing condition between the reservoir and the Dayton Hollow Dam. Stabilizing the reservoir around 1060 feet msl, though less than optimal for the reservoir fishery, would provide about 1.0 mile of riverine conditions above the reservoir.

Cultural Resources

In 1981, a preliminary survey was undertaken to determine whether any significant cultural resource sites were present on project lands directly adjacent to the reservoir. Two, possibly three, prehistoric sites were located, and other sites are probably present. These areas are on top of the higher banks along the south and eastern shores. Unfortunately, these are the areas being eroded at the fastest rate by wave action.

Additional survey work is scheduled for summer 1985 under funding separate from this study. However, the survey work and this operating plan reevaluation are being coordinated to provide the maximum possible contribution toward preserving the significant cultural resource sites.

Recreation Resources

Introduction - Recreation benefits are generally evaluated based on the distance people are willing to travel in order to reach the recreation site. For this evaluation, a 75-mile radius from the Orwell project is assumed to include the majority of people that would be drawn to a new recreation activity. Populated areas within 75 miles of the Orwell Reservoir that could be considered potential draw areas include the following cities.

City and State	1980 Population	Miles
Fergus Falls, Minnesota	12,519	6-7
Breckenridge, Minnesota	3,909	20
Detroit Lakes, Minnesota	7,106	50
Alexandria, Minnesota	7,606	50
Moorhead, Minnesota	29,998	52
Wadena, Minnesota	4,699	55
Park Rapids, Minnesota	2,976	56
Fargo, North Dakota	61,281	60

Major cities (over 10,000 population) contribute to participation at recreational activities in the Orwell area. Interstate Highway I-94 passes about 10 miles from the Orwell project and may contribute to recreational development in the area by providing a high quality transportation link.

The 75-mile draw area also includes counties that contain significant numbers of potential recreation-seekers from rural and agricultural areas. Figures 2 through 6 indicate that some of these counties have substantial existing recreation resources. Thus, it would be reasonable to assume that people in the resource-rich counties would not leave their own areas, except for activities in short supply. Supply and demand help determine how far people are willing to travel for recreation. Because the counties bordering the Red River appear to have fewer recreation opportunities, those people are more likely to leave their areas to sites such as Orwell and others in Minnesota.

Regional Recreation Features - Waterfowl hunting and deer hunting are the two most popular sportsman activities within Region 5 of North Dakota (see figure 2). Richland and Ransom Counties have the most public hunting acres available in Region 5, but many participants in hunting and fishing go elsewhere in the State, or to Minnesota, where the proper topography and other natural physical features are available. Most participants travel to Minnesota for cross-country skiing, powerboating, waterskiing, sailing, and swimming.

A national scenic hiking trail, called the North Country Trail, designated in 1980, begins at Wahpeton and leads northwest along the Sheyenne River valley and continues through the Devils Lake basin. See figure 3 for the Minnesota recreational trails located within the 75-mile draw area.

Waterfowl Production and Wildlife Management Areas

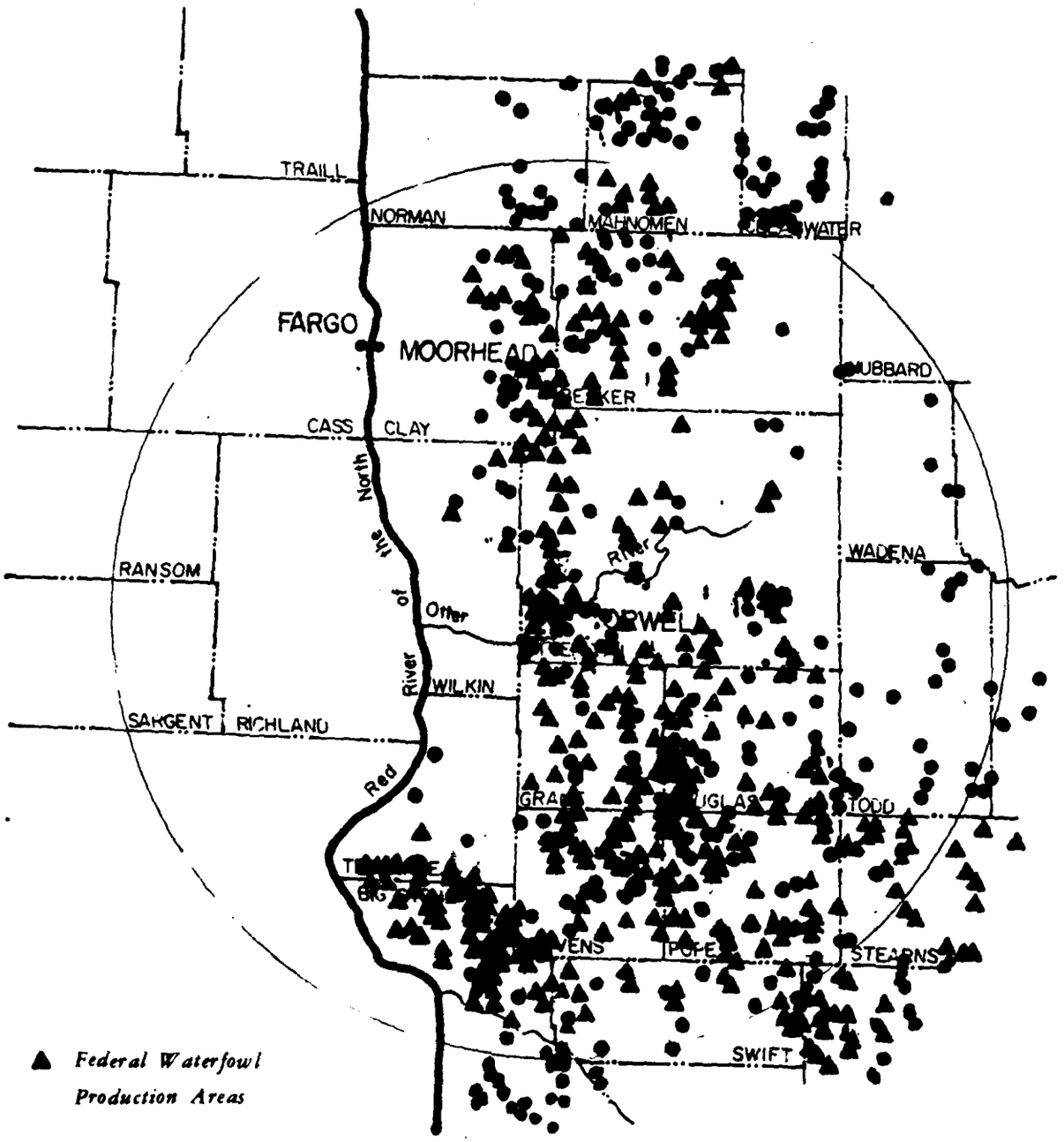


FIGURE TWO

Minnesota Recreational Land Trails

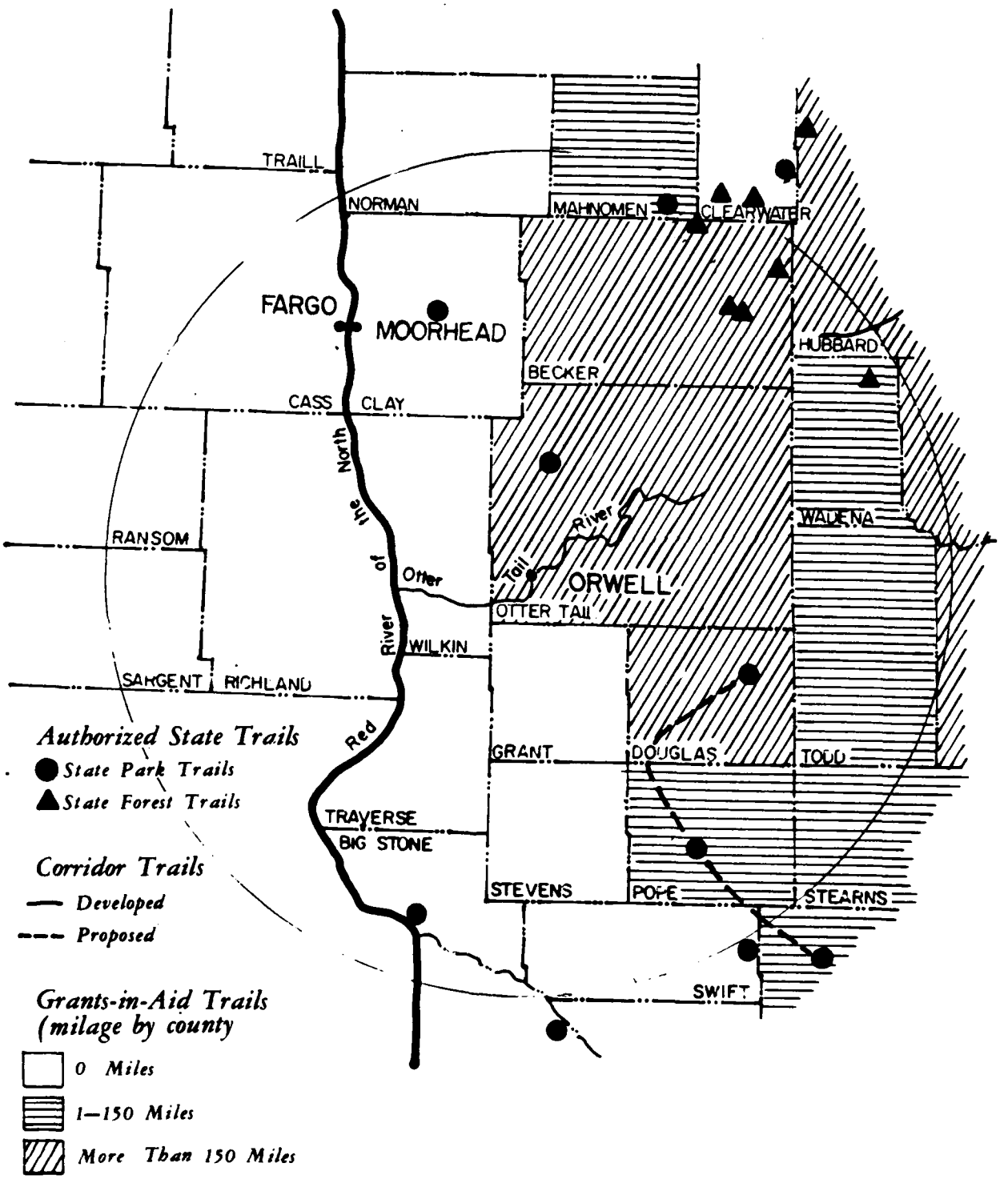


FIGURE THREE

Scenic Areas

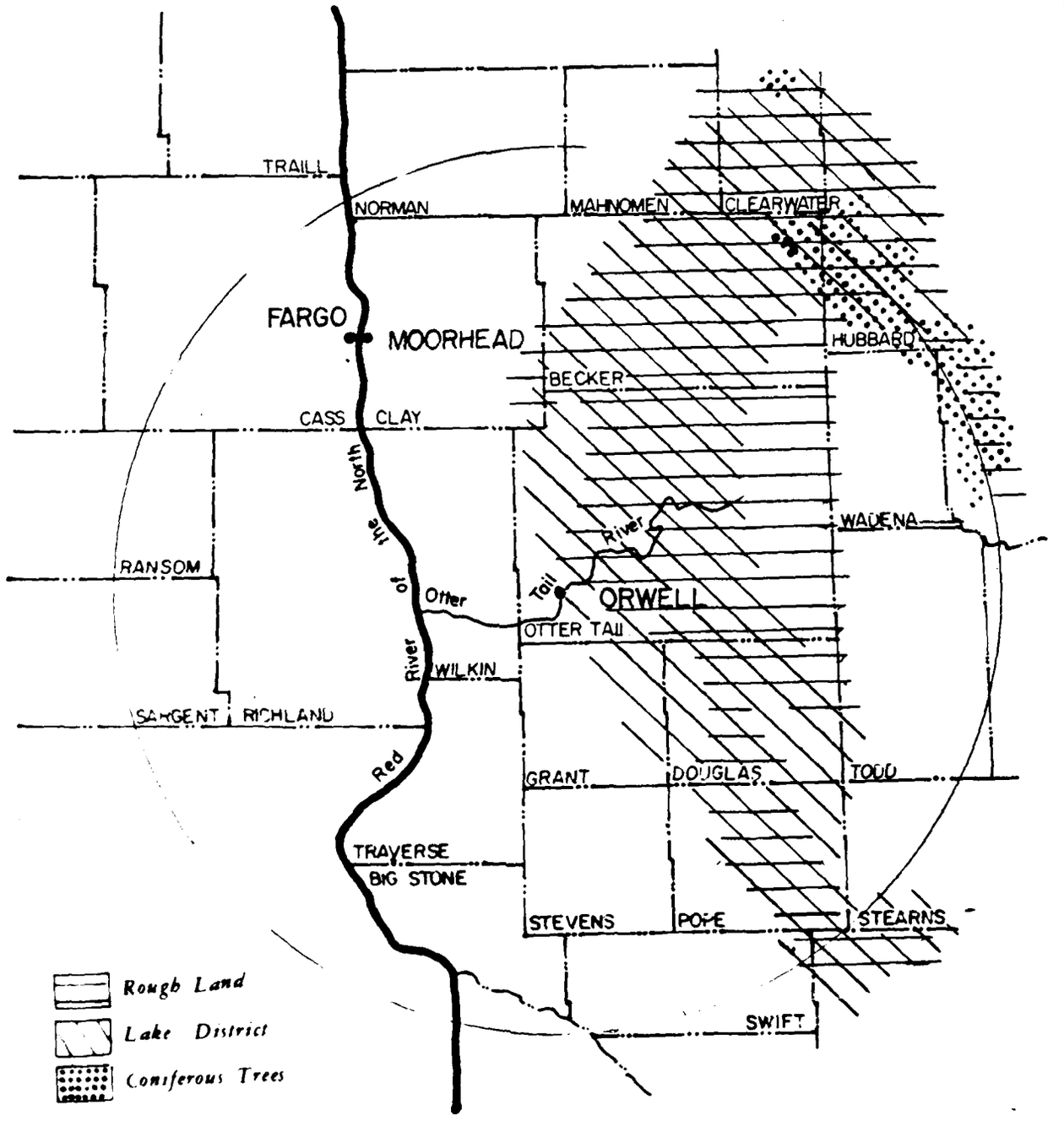


FIGURE FOUR

curves. Only run-of-river (no peaking) operation will be evaluated using the schedule of flow releases formulated for the other purposes.

Fisheries

The potential project feature of more stabilized pool levels will be evaluated to determine the benefit for the lake fishery and the effect of the pool stabilization on the other purposes. The fishery in the Otter Tail River will be evaluated to determine the potential benefit of supplementing summer flows and minimizing the rate of change of dam releases.

Wildlife

Subimpoundments in the south arm of the reservoir will be evaluated to determine their effectiveness in contributing to wildlife. Their effect on other purposes will also be determined. More stable pool levels and other potential project features will be better defined and evaluated for effectiveness.

Cultural Resources

An additional field survey will be undertaken for areas not covered in the previous survey. Identified cultural resource sites will be evaluated for eligibility to the National Register of Historic Places. Project features to reduce shoreline erosion will be evaluated to reduce the loss of significant identified cultural resource sites.

Shoreline Erosion

Project features were recommended in a previous study by John Reid of the University of North Dakota. Those features will be evaluated as to their effectiveness and impact on other identified purposes.

for chemicals used to purify water for municipal and industrial supply. Supplementing summer flows should improve Red River quality and reduce the amount of ground-water pumping. Other benefit categories may also apply.

Water Supply

More information will be obtained to determine what short term problems exist and how the Orwell project might help solve them. Long term problems and water supply planning would require a much larger scale effort than is possible within the resources of this reevaluation of the Orwell operating plan. One potential need is that some basin-wide agency, possibly the Corps of Engineers, should take the lead in comprehensive water supply planning for the Red River basin. However, the two States involved would have to support the work in order to do an effective job.

Recreation

Before deciding to provide any additional recreation activities at Orwell Reservoir, an evaluation will be made of the influencing characteristics and surrounding land uses to determine the suitability and relative value in comparison to the regionally available activities. A review of available information about existing activities and an inspection of the project area is tentatively scheduled for June 1985. The Otter Tail River will be inspected and evaluated to determine suitability for additional development as a canoe route. The Minnesota Department of Natural Resources (MDNR) has indicated interest in the Otter Tail River as a canoe route.

Hydropower

A reconnaissance level feasibility evaluation will be accomplished using the existing discharge rule curves and possibly one or two alternative

EVALUATION

INTRODUCTION

Evaluation of Federal water resource projects, such as the Orwell project, is required by public law to be accomplished according to Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, dated March 10, 1983. The principles and guidelines specify how to assess the magnitude of effects a project has on its purposes and significant resources. Standard engineering, environmental, and economic principles are used in the procedures to determine a relative value for the project's contributions to each purpose.

The following paragraphs summarize the important evaluation activities required for each identified purpose. Some evaluation activities are intended to determine how well the existing operating plan is performing, and other activities will determine the performance of alternative operating plans.

EVALUATION ACTIVITIES

Flood Control

Land use data and surveys of flood-prone structures will be obtained for Wahpeton, Breckenridge, and the flood-prone agricultural areas. The Otter Tail River discharge-frequency curve will be updated and combined with existing profiles from the 1978 flood insurance study for Wilkin County, Minnesota, and the nearly complete flood insurance study for Wahpeton, North Dakota.

Pollution Abatement

Activities will include determining all benefit categories applicable to the project. One category will likely include the reduced use and cost

Potential Project Features

Planning Objectives	Stone Shoreline Protection	Stabilize Pool Elevation	Supplement Summer Low Flows (a)	Increase Storage (c) of Floods	Increase Channel Capacity (a)	Urban Flood Control Features	Raise Orwell Dam 4 Feet	Change Lake Traverse Releases	Subimpoundments in South Arm	Reduce Rate of Change in Releases(6)	Small Hydropower Unit
1. Stream Fishery & Sportfishing (a)			●	●			●			●	
2. Stream Fishery & Sportfishing (b)		●		●							
3. Lake Fishery & Sportfishing	●	●		●			●				
4. Canoeing, etc. on Ottertail R.			●	●			●			●	
5. Agricultural Flood Damage Reduction				●	●		●				
6. Urban Flood Control				●		●	●				
7. Water Supply			●	●			●				
8. Water Quality			●	●			●	●			
9. Recreation at Reservoir		●		●					●		
10. Wildlife & Hunting		●		●			●		●		
11. Cultural Resources	●	●	●	●							
12. Shoreline Erosion	●	●	●	●							
13. Hydropower		●		●			●			●	
Number of Objectives	3	6	6	13	1	1	9	1	2	2	1

(a) On the Ottertail River, downstream from the Orwell Reservoir.

(b) On the Ottertail River, between the Orwell Reservoir and the Dayton Hollow Dam.

(c) In the Ottertail River Basin, upstream of the Orwell Reservoir.

Hydropower

Consider a small run-of-river unit. A hydro turbine may provide an additional low-flow outlet to supplement the two existing inadequate conduits.

Cultural Resources

Eliminate shoreline erosion. See the discussion above of the Potential Project Features to control shoreline erosion. Complete the survey of project lands for significant cultural resources.

CATEGORIZED PROJECT FEATURES

The following table provides graphic information concerning groups of compatible project features and planning objectives. The table may oversimplify the objectives and features. It also does not indicate the magnitude of contributions, nor does it indicate negative effects. The table leads the reader to believe that increasing upstream storage and raising Orwell Dam would provide the most net benefits because they contribute to the largest number of objectives. However, the cost and implementability are extremely questionable. The two project features of stabilizing pool levels and supplementing summer low flows appear at this preliminary stage to hold the most potential for maximizing net benefits while possibly not reducing benefits for the authorized purposes. The following chapter summarizes the evaluations that are necessary for these potential project features.

Wildlife

Provide for subimpoundments on the south arm of the pool and outlets to control their water levels. This measure would require coordination with or reduction of the main pool elevations. Stabilize main pool fluctuations (raise minimum pool and lower maximum pool) to something much less than the present 22-foot pool fluctuation and decrease the duration of levels held at maximum flood control pool. This stabilization would create riparian and shallow water habitats and possibly allow aquatic plant establishment. Reduce shoreline erosion. Slow down rate of reservoir level fluctuation.

The Minnesota Department of Natural Resources listed these additional features in their February 4, 1985, office memorandum for the wildlife management area and the reservoir: fencing, access sites and parking lots, road improvements, vegetation management on the islands, and water control capability for the Type 4 wetland that straddles sections 35 and 36 just north of CSAH 2.

Fishery

Stabilize main pool fluctuations to levels such as elevations 1065 to 1067 feet msl. This stabilization would encourage establishment of a littoral zone with aquatic plants. Supplement Otter Tail River flows during summer low-flow periods and minimize rate of change in flows, especially when reducing flows. This change in flows would provide more stable flows for fish and mussels and should encourage increase in game fish and other populations. Also, reduce shoreline erosion. Slow down rate of reservoir level fluctuation.

Water Supply

Supplement summer low flows with water from Orwell Reservoir. Dilute discharges from Lake Traverse with water from Orwell Reservoir. Reduce or eliminate large slug type releases from Lake Traverse.

Recreation

In order to provide water contact activities in the reservoir, control shoreline erosion, and hold the pool level more stable. Increased wildlife and fisheries production would contribute to sportsman opportunities. Canoeing, fishing, and other day-use activities on the Otter Tail River would benefit from supplementing summer low flows with releases from the reservoir.

Flood Control

Increase storage of flood flows in the Otter Tail River basin by taking better advantage of other existing lakes and reservoirs. Increase or maintain the channel capacity of the existing channel improvement downstream of Orwell Reservoir. Consider urban flood control projects for Wahpeton and Breckenridge. Raise Orwell Dam by up to 4 feet to provide additional flood storage capability.

Shoreline Erosion

Reduce the amount of time that the pool elevation is held over elevation 1067.9 msl; or provide stone riprap for shoreline protection at an estimated cost of $250,000.

Water Quality/Pollution Abatement

Shift releases to summer low-flow periods rather than the following fall and winter. Decrease the maximum Lake Traverse releases when the lake water quality is worst and storage does not conflict with authorized purposes. Evaluation of the Lake Traverse operation would require a separate study.

8. Contribute to water quality in Orwell Reservoir, the Otter Tail River, and the Red River as far downstream as Fargo-Moorhead (also implies pollution abatement in the two rivers).
9. Contribute to the day-use activities associated with Orwell Reservoir and the Otter Tail River downstream from Orwell and Dayton Hollow Dams.
10. Contribute to wildlife resources and hunting opportunities associated with Orwell Reservoir.
11. Reduce shoreline erosion on Orwell Reservoir and erosion encroachment on surrounding public and private lands.
12. Contribute to protection and preservation of cultural resources on project lands or other areas affected by project operations.
13. Contribute to the use of renewable energy sources such as hydropower to reduce the use of nonrenewable fossil fuels and to provide a less costly energy source.

PLAN FORMULATION

INTRODUCTION

Plan formulation will not be accomplished in detail until this problem appraisal report has been coordinated with the public. However, potential project features are being collected and documented with the related problem, need, or opportunity. Later, the potential project features can be put together with other compatible features to form preliminary alternatives. It is likely that a preliminary plan would be recommended for testing over a number of years, possibly as many as 5 years.

POTENTIAL PROJECT FEATURES

The following project features and related studies should be considered.

PRELIMINARY PLANNING OBJECTIVES

Planning objectives are resource-oriented statements intended to specify problems, needs, and opportunities identified during public involvement. The statements attempt to reflect the events and results that are desired by groups and individuals, as well as those declared to be in the national interest by the Congress or the Executive Branch. The objective statements may be changed as the problem definition process continues. The statements attempt to define the problems and opportunities without dictating a narrow range of alternative solutions. The objective statements are intended to define future desired conditions as well as desired present conditions. The preliminary planning objectives are stated as follows:

During the period of analysis (1985-2035):

1. Contribute to the stream fishery and sport-fishing recreation opportunities in the Otter Tail River below Orwell Dam.
2. Contribute to the stream fishery and sport-fishing recreation opportunities in the Otter Tail River below Dayton Hollow Dam and above Orwell Reservoir.
3. Contribute to the lake fishery and sport-fisning recreation opportunities in Orwell Reservoir.
4. Contribute to canoeing and other recreational uses on the Otter Tail River between the mouth and Orwell Dam.
5. Reduce agricultural flood damage in the Otter Tail River floodplain below Orwell Dam.
6. Reduce urban flood damage from the Otter Tail River at Breckenridge, Minnesota, and Wahpeton, North Dakota.
7. Contribute to surface and ground-water supplies (municipal and industrial, irrigation) from Orwell Reservoir, the Otter Tail River below Orwell Dam, and the Red River of the North downstream to Fargo/ Moorhead.

PLANNING CONSTRAINTS

Some of the concerns received from the public cannot be appropriately expressed as problems, needs, or opportunities. Such concerns are more properly labeled "planning constraints." Planning constraints also include law, national policy, physical constraints, or any other limitation that can be used to refine and guide formulation of alternative solutions to the stated planning objectives. The following list summarizes the planning constraints identified for this study.

1. Federal law, State statutes, and local ordinances and regulations, as well as national water resource policy.
2. Bank-full capacity of the Otter Tail River downstream of the Orwell Reservoir is presently estimated to be 900 cfs.
3. The Dam Safety study, scheduled to be completed in April 1985, and the physical dimensions of the project limit the useful storage of Orwell Reservoir.
4. Instream requirements of the Otter Tail River downstream of Orwell Reservoir limit the minimum releases on a seasonal basis. These requirements also limit the desired rate of change in reservoir releases.
5. The existing low-flow outlets and single tainter gate limit the amount of precise control over releases and reservoir pool elevation.
6. A Corps agreement with the U.S. Fish and Wildlife Service reserves the volume of water below pool elevation 1048 msl for fisheries.
7. Rates and amount of inflow to Orwell Reservoir from Dayton Hollow Reservoir and other related hydrologic constraints.
8. The presence of rough fish in the reservoir limits the value of the aquatic habitat for more desirable fish species.

marginally feasible. If such a pool stabilization appears to be consistent with the authorized and other considered purposes, then hydropower would be considered. Peaking operation for hydropower will not be considered because the related fluctuations of pool level and discharges are inconsistent with existing authorized and recognized purposes.

Downstream Channel Capacity

Channel capacity is defined for the purposes of this discussion as the maximum flow rate a channel can pass without causing significant flood damages. More precisely, it is the zero damage discharge. The design discharge for the Otter Tail River channelization project between river miles 9.7 and 21.1 is 900 cfs. The channel project was constructed by the Corps and is maintained by the local project sponsor. The channelization project was found to be in very good condition during the last inspection. The condition of the Otter Tail River channel upstream of river mile 21.1 is unknown. Reports from the public, such as canoeists, indicate that some clearing and snagging of trees, stumps, and debris may be needed. The channel will be inspected to determine its condition and discharge will be measured to determine its likely channel capacity. It may be determined that additional clearing and snagging or other channel work is needed.

The 900 cfs design discharge figure is currently used by the St. Paul District Water Control Center as the maximum total release from Orwell Reservoir to prevent induced flood damages in downstream agricultural and urban areas. The 900 cfs figure may be overly conservative, and a larger discharge may be possible without causing flood damage. District records show that in April 1979, the Orwell Dam was releasing 1,100 cfs and the Otter Tail River was still in its banks. If the actual channel capacity is determined, then the Water Control Center would have great operation flexibility during the smaller floods. The larger floods would continue to occur, unmoderated by the Orwell project, as occurs with the existing project operation.

Canoeing has shown the greatest increase in participation recently. The Sheyenne and Red Rivers are highly suitable for canoeing. The Otter Tail River also is a popular canoeing river and is being considered for improvement by the Minnesota Department of Natural Resources.

In summary, recreation activities that rank the highest for Region 4 in Minnesota for needs and desires include the following, in order:

1. Interpretive facilities (historical, nature study) and natural park areas.
2. Upland game and waterfowl hunting - demand for Region 4 is greater than the State-wide demand.
3. Trail facilities, including canoeing and cross-country skiing.
4. Water-related activities (river access, fishing, swimming, camping, boat launches, and picnic areas).

Orwell is located in a projected high-demand area for the following activities:

Hiking	Visiting Historical Sites
Camping	Driving For Pleasure
Picnic	Sledding
Bicycling	Swimming

Hydropower Potential

The Orwell Dam was considered during the National Hydropower Study conducted by the Corps in 1978. During that simplified and preliminary evaluation, a hydropower project at Orwell Dam was determined to be infeasible. A 1.6-megawatt unit was considered, ing the flows from the reservoir as they were released under the existing operating plan. Later, the St. Anthony Falls Hydraulics Lab in Minneapolis, Minnesota, reevaluated the site using slightly different assumptions concerning the operating plan. The lab found that if the 22-foot pool fluctuation that presently occurs could be stabilized, a small hydropower unit might be

Major Federal Management Units Offering Outdoor Rec. Opportunities

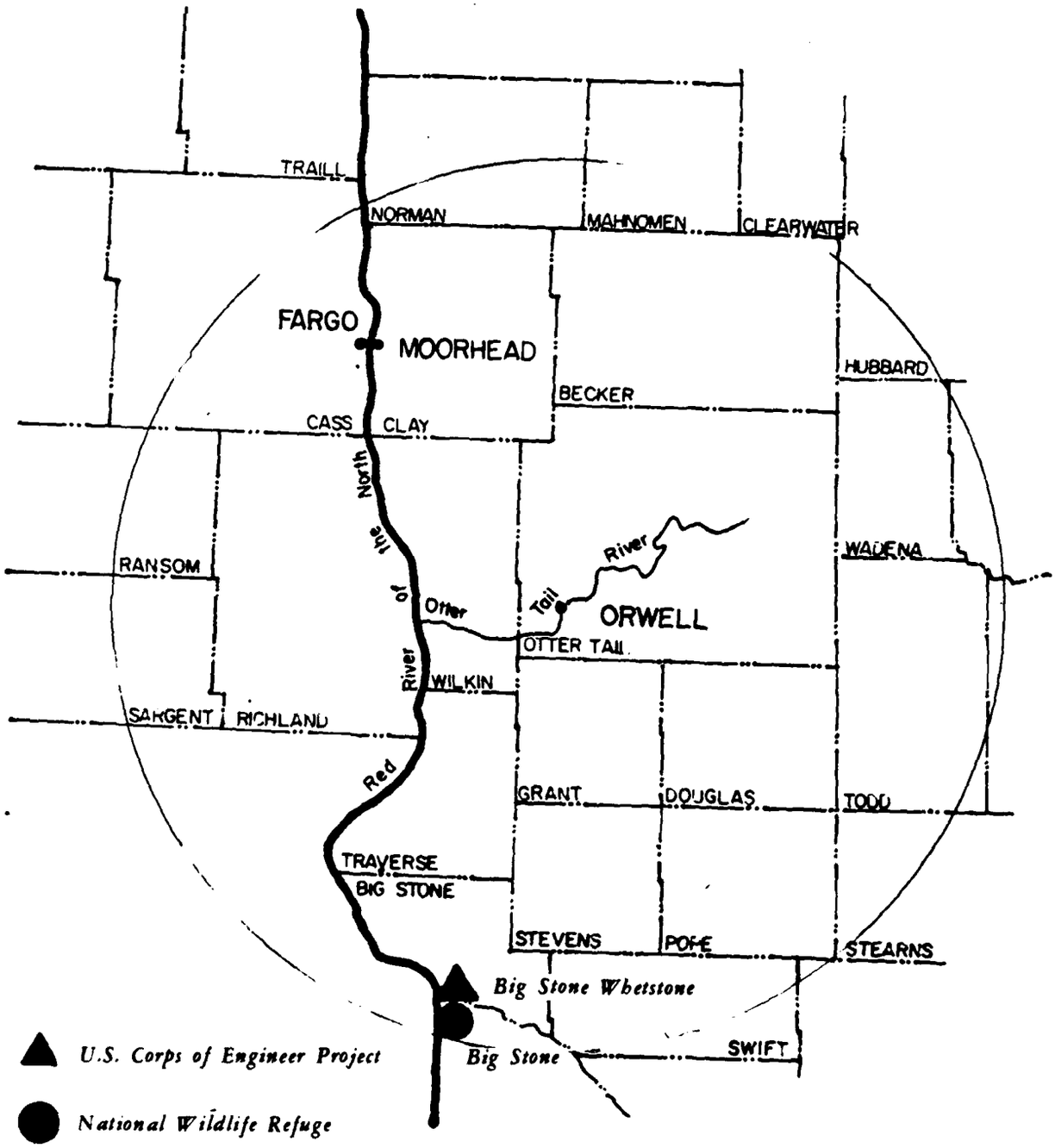


FIGURE SIX

Distribution of State Parks, Recreation Areas & Waysides Among Landscape Regions

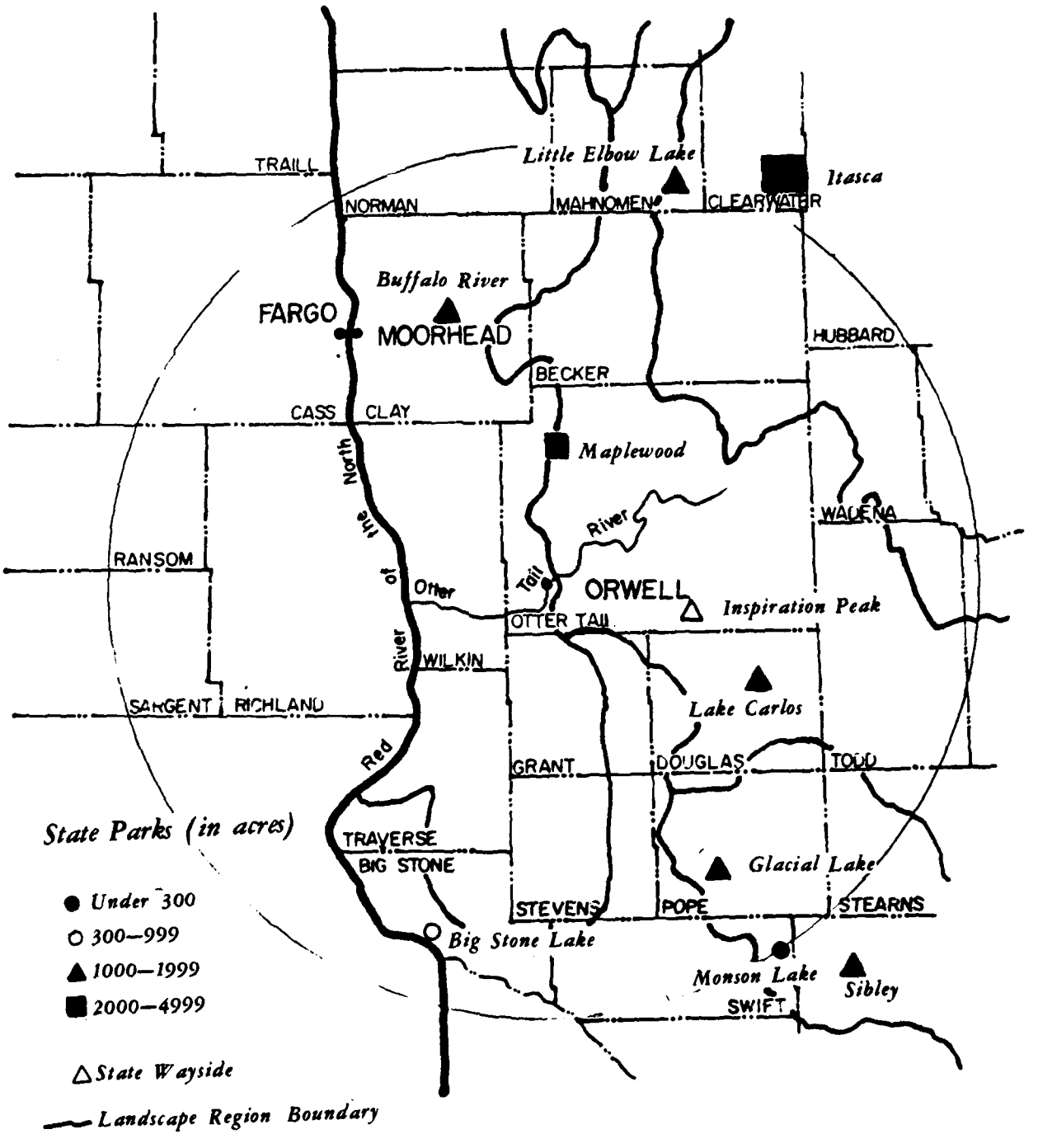


FIGURE FIVE

Downstream Channel Capacity

Field measurements will be made in attempt to verify the channel capacity of the Otter Tail River downstream of Orwell Dam. These measurements should also determine the accuracy of the tainter gate settings under the prevailing conditions.

ENVIRONMENTAL CONSIDERATIONS

Environmental considerations will play an important part in the Orwell Reservoir Operating Plan Evaluation (ROPE) study. The Otter Tail River and the Orwell Wildlife Management area are important natural resources of the region. Orwell Reservoir has the potential to be an important natural resource. Input from Federal and State resource management agencies has been actively sought during the problem appraisal phase of the study. We will continue to seek input from these agencies as well as the public during the remainder of the ROPE study.

Depending on the recommendations of the ROPE study, further environmental documentation may be required. If the study recommends no change in the current operation of the reservoir, no further environmental documentation will likely be required. If a change in operation is proposed, preparation of environmental documents will be required to evaluate the effects of the proposed change. A minor change in the operating plan with no significant impacts would require the preparation of an environmental assessment/FONSI.

A significant change in the operation of the reservoir may require the preparation of an environmental impact statement.

ACTIVITY SCHEDULE

Coordinate Problem Appraisal Report	February 1985
Draft Orwell ROPE Report	September 1985
Final Orwell ROPE Report	November 1985
Update Of Reservoir Operation Manual (Tentatively Scheduled by Water Control Center)	Fiscal Year 1987

The draft Orwell ROPE report likely will contain tentative recommendations for testing a modified operation plan for Orwell Reservoir. If the test is acceptable to the affected public, recommended by the St. Paul District Engineer, and approved by the North Central Division Engineer, then the test would likely commence in the spring of 1986. A 5-year test period would likely be used as has been done at other Corps-operated reservoirs in the St. Paul District.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations statements included in this report are preliminary. More precise and additional statements will be made in the Orwell ROPE (Reservoir Operating Plan Evaluation) report, scheduled to be published in September 1985.

CONCLUSIONS

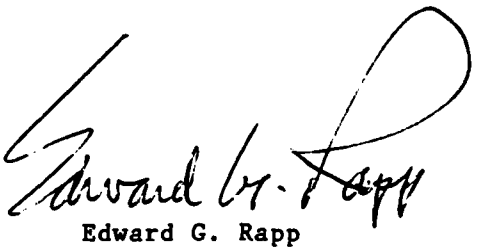
1. The Orwell ROPE study will be limited to considering the potential effects of alternative operating plan modifications in the project area.
2. Additional low-flow release controls are needed, either to supplement or to replace the existing low flow conduits.
3. Public concerns about water quality and quantity include the operation of Lake Traverse. A ROPE type study should be considered for Lake Traverse if there are sufficient other problems and concerns involved with its operation.

4. Water supply is a continuing concern of the four downstream urban areas most affected by Orwell operation. The reservoir is a factor in the quality of their supply in normal precipitation years. However, the reservoir has little effect during sustained droughts because the four cities have ground-water systems to at least supplement surface water supplies.
5. Urban flood damages continue to occur at Wahpeton and Breckenridge from the Otter Tail and Red Rivers. Agricultural flood damages continue to occur along the Otter Tail River. Flood control will continue as an authorized purpose of the Orwell project.
6. The pollution abatement problem has changed since the Orwell project was originally formulated, designed, and authorized. Releases from the Orwell project to supplement and improve the quality of river flows are now needed more during the summer low-flow periods than during the fall and winter as originally intended.
7. Shoreline erosion and the absence of shoreline vegetation is a continuing serious problem at Orwell Reservoir. The erosion could probably be reduced most effectively by reducing the length of time the pool is held at or over elevation 1067.9 msl.
8. Fish and wildlife are an important resource of the project area and are of significant concern to the Minnesota Department of Natural Resources. The single most effective potential action to benefit fish and wildlife would be to reduce the present 22-foot pool fluctuation. Other features should also be considered, such as subimpoundments in the south arm of the reservoir.
9. Additional cultural resource surveys are being done to complete the survey of all Orwell project lands. Reduction of shoreline erosion would help preserve any potentially significant sites present.
10. Recreation continues to be an important benefit from the Orwell project. Additional benefits would accrue if summer low flows on the Otter Tail River were supplemented with storage from Orwell Reservoir. Additional potential recreation features will be considered.

11. Hydropower potential is probably economically marginal, with a less than one megawatt capacity plant having the best chance of being feasible. Peaking operation will not be considered for any potential hydropower alternative.
12. The downstream Otter Tail River channel capacity is probably greater than the 900 cfs figure presently used by the Water Control Center. A larger figure would give Water Control increased flexibility during flood control operations.
13. During routine inspections of the stilling basin, a continuous discharge is needed to the Otter Tail River downstream of the basin. Under current conditions, the stilling basin is dewatered for inspections and both low-flow outlets and the tainter gate must be closed during the dewatering.

RECOMMENDATION

It is recommended that the Orwell Rope study be completed as described in this problem appraisal report and scheduled to be approved in November 1985.



Edward G. Rapp
Colonel, Corps of Engineers
District Engineer

PERTINENT DATA

General

Total drainage area	1,820 square miles
Effective drainage area (below main lake region)	245 square miles

Reservoir

Pool elevation at spillway design flood	1075.0	feet msl
Capacity at spillway design flood elevation	20,400	cfs
Normal full pool elevation	1070.0	feet msl
Normal low pool elevation	1048.0	feet msl
Fee title to elevation	1073.0 ±	feet msl
Capacity at normal full pool (elevation 1070.0)	14,100	acre-feet
Capacity at normal low pool (elevation 1048.0)	1,000	acre-feet
Effective storage capacity	13,100	acre-feet
Reservoir area at normal full pool	1,110	acres
Reservoir area at normal low pool	210	acres
Reservoir length at normal full pool	4.0	miles
Maximum reservoir width at normal full pool	1.0	mile

Dam

Type	Rolled earth fill	
Crest elevation	1080.0	feet msl
Maximum height	47	feet
Top width	20	feet
Length of earth fill	1,355	feet
Embankment side slopes	1 on 3	
Total volume of earth fill	168,165	cubic yards
Freeboard above maximum elevation of spillway design flood	5.0	feet

Dikes

Number	2	
Crest elevation	1080.0	feet msl
Maximum height	10	feet
Total length	1,140	feet
Total volume of earth fill	9,521	cubic yards

Spillway

Type	Gated ogee and chute	
Crest elevation	1044.0	feet msl
Length of spillway crest	33	feet
Elevation top of tainter gate (closed)	1071.5	feet msl
Design discharge (surcharge 5 feet)	20,400	cfs
Volume of concrete in structure	9,310	cubic yards

Outlet Works

Low Water Control

Size	2 feet inside diameter	
Number	2	
Invert elevation	1040.0	feet msl
Discharge capacity (total for both gates) at normal full pool (1070.0)	150	cfs
Gates	Two hand-operated 24" AWWA M&H iron body double disc gate valves	

Stilling Basin

Type		flared
Length	72	feet
Floor elevation	1024.5	feet msl
Elevation of end sill	1032.5	feet msl
Maximum width at end sill	78.5	feet

ORWELL ROPE

(RESERVOIR OPERATION PLAN EVALUATION)

PROBLEM APPRAISAL REPORT

CORRESPONDENCE APPENDIX

ORWELL ROPE

(RESERVOIR OPERATION PLAN EVALUATION)

PROBLEM APPRAISAL REPORT

CORRESPONDENCE APPENDIX

LAND OF QUALITY FOODS

STATE OF MINNESOTA
DEPARTMENT OF AGRICULTURE

90 W. PLATO BOULEVARD
SAINT PAUL, MN 55107
Telephone: (612) 296-1488

January 9, 1985

District Engineer
Attn: Herb Nelson (NCSPD-PF/Orwell)
St. Paul District, Corp of Engineers
1135 U.S. Post Office & Custom House
St. Paul, Minnesota 55101-1479

Dear Mr. Nelson:

I'm sorry it has taken me so long to reply to your request for comments on the Orwell Dam and Reservoir Study. As I indicated in our telephone conservation, I believe the main concerns the Minnesota Department of Agriculture would have would be related to protecting agricultural land from encroachment by the project, the protection of agricultural land from flooding, any soil erosion caused by management of the project, and perhaps any impact proposed management practices would have on area irrigation.

Please let me know if I can be of further assistance.

Yours truly,

MINNESOTA DEPARTMENT OF AGRICULTURE

Paul Burns

Paul Burns
Environmental Review Coordinator
Planning Division

PB:dw

CITY OF FARGO

NORTH DAKOTA

WATER
DEPARTMENT

KENNETH RUBY
SUPERINTENDENT

January 11, 1985

Herb Nelson
U.S. Corps of Engineers
St. Paul District
1135 U.S. Post Office & Custom House
St. Paul, Minnesota 55101-1479

Attn: NCSPD-PF/Orwell

Dear Mr. Nelson:

The City of Fargo is vitally concerned with the operation of Orwell Dam and Reservoir, both for water supply and pollution control.

In the past the plan of operation has worked very well in providing a water supply to the City of Fargo. I would not like to see it altered materially for that purpose. However summer operation still should consider pollution abatement.

Fargo's NPDES Permit sets limits on Biochemical Oxygen Demand, Suspended Solids, pH and Coliform Bacteria in the effluent from the Sewage Treatment Plant. It also sets limits on the total pounds of B.O.D. that can be discharged per day. The pounds of B.O.D. vary according to the flow in the Red River. To date this limitation has never been a problem since the quality of our effluent has always been well below the standards permitted.

There could be a future problem however with ammonia. There is no ammonia limitation in our Discharge Permit at the present time, however, I believe there will be one in the future.

The past summer the North Dakota State Health Department required the City to monitor ammonia in the discharge from the treatment plant and in the river above its discharge point and the river below its discharge point. They then limited the quantity of our discharge per day based on the ammonia analyses, pH, temperature and the flow of the river.

The City of Fargo has a secondary trickling filter plant followed by six-90 acre waste stabalization ponds. The City's discharge permit doesn't allow any discharge under ice cover in the river. Therefore, the City can only discharge in the warmer months and store the sewage all winter.

The past summer the City's discharge was seriously limited due to the low flow in the river, particularly in August when the flow was under 100 cfs. We had no problem with B.O.D. or suspended solids but we did have a problem with the ammonia. The Health Department was afraid of a fish kill in the river if the ammonia content in the river got too high.

I hope that you will consider the above comments when evaluating any new plan for operation of Orwell Dam and Reservoir.

Sincerely yours,

Kenneth Ruby

Kenneth Ruby, Director
of Utilities

WAHPETON

PHONE (701) 642-8449

CITY HALL
WAHPETON, NORTH DAKOTA 58075

January 15, 1985

District Engineer
ATTN: NCSPD-PF/Orwell
St. Paul District, Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101-1479

Dear Sir;

The City of Wahpeton has received notice of the study to re-evaluate the operation of Orwell Dam in Minnesota. We are concerned about the operation of the dam as it does affect our city during flood time and also during low water periods in the summer months.

Please include the City of Wahpeton on your list of notices concerning any activities on the study and all proposed changes. If you have a current operation plan of Orwell Dam we would appreciate a copy of it also.

Thank you and should you require any information from us please feel free to contact me at any time.

Yours truly,

Jerry C. Lein
City Engineer

JCL/dm
CC: City Council

DEPARTMENT MDNR-Div. of Waters-Box 32

TO : Gary Palesh
Corps of Engineers

DATE: February 15, 1985

FROM : Joe Gibson
Federal Projects Coordinator

PHONE: 296-2773

SUBJECT: ORWELL RESERVOIR - ROPE

Attached is a memo containing the comments that I have received regarding the reevaluation of the Orwell Reservoir operating plan. If you have additional questions, please contact me.

JCG:sr
Attachment

J-1

STATE OF MINNESOTA

Office Memorandum

DEPARTMENT NATURAL RESOURCES
Fish and Wildlife

TO : Joe Gibson
Division of Waters

RECEIVED
FEB 0 6 1985
Division of Waters

DATE: February 4, 1985

FROM : Larry R. Shannon, Director
Division of Fish and Wildlife

PHONE: 297-1308

SUBJECT: Orwell Reservoir - Corps ROPE Study

Attached is an outline of problems, planning constraints, and opportunities which the Division of Fish and Wildlife would like to have incorporated into the Corps ROPE (Reservoir Operating Plan Evaluation) Study for the Orwell Reservoir. This response was developed by Ecological Services staff in coordination with Regional and Area Fisheries and Wildlife personnel.

The Orwell WMA contains some excellent wildlife habitat and has value as a production area as well as a migration and wintering area. Care must be taken so that "improvements" to the Operating Plan do not result in more harm than good to these resources. Related to this is the fact that the waterfowl refuge currently harbors thousands of ducks and geese during fall migration. Nothing should change in the operation of the reservoir which would reduce the value of the refuge.

It is our feeling that providing wildlife habitat in the reservoir and adjacent areas and providing adequate downstream flows for fisheries should be the primary concern of the Reservoir Operating Plan. Any improvements that are made in the main pool area such as reducing water level fluctuations, optimizing water levels in the reservoir, bank stabilization, etc. will benefit both fisheries and wildlife. There is currently some good fish habitat in the upper reaches of the reservoir (below Dayton Hollow Dam) and in the tailwaters of the Orwell Dam and these two areas should be maintained or enhanced as fish habitat.

We feel, in conjunction with an improved Reservoir Operating Plan, that the most practical method for improving waterfowl and wildlife production of the WMA would be to subimpound various sites both on the south flowage area and on areas immediately adjacent to the main pool. Control structures should be designed that would provide permanent, stable wetlands (with drawdown capacity) and would also control rough fish movement into these areas. Based on our limited knowledge, we would assume that such structures would not seriously detract from the flood storage potential of the reservoir.

We are aware that periodic routine inspection of the stilling basin is needed and that such inspections require dewatering of the stilling basin. The existing low flow conduits discharge into the stilling basin and cannot be used during inspection. Some means of providing a continuous discharge to the river downstream of the dam during the routine inspections should be addressed in the ROPE Study.

Any specific operational features are difficult to specify without additional information. Specifically, we would require a topographic map of the reservoir, preferrably in 1 or 2 foot intervals, reservoir level and flow data for a series of years similar to the curve already provided, and a copy of the erosion control study conducted by John Reid at North Dakota State University.

Besides changes in the operation plan, there are other features of the reservoir and WMA which could be improved. These include fencing, access sites and parking lots, road improvements, vegetation management on the islands, and water control capability for the Type 4 wetland which straddles sections 35 and 36 just north of Highway 2. The ROPE study may be a good place to address some of these improvements.

We have recently received copies of four draft objective statements and follow-up narratives for the Problem Appraisal Report for Orwell Reservoir. We are encouraged by the draft objective statements and information contained in the narratives. We suggest that the Corps modify and/or expand the objective statements and narratives based on the information we are providing in the correspondence. We would like to review and comment on the revised draft prior to incorporation into the Problem Appraisal Report. Specifically, we would recommend that the objective dealing with fish and sport fishery enhancement in the main reservoir be modified to address wildlife concerns in the reservoir. Wildlife management continues to be our highest priority on this site.

We appreciate the efforts that the Corps has made to solicit inputs from the Division of Fish and Wildlife during this early stage of planning and look forward to continued cooperation as the project proceeds.

LRS:DS:db

cc: Larry Seymour
Richard Hassinger
Roger Holmes
Jack Skrypek
Robert Farms
Stan Daley
Gordy Nielsen
Don Reedstrom
Earl Huber
Joe Geis
Jack Enblom
Dave Schad

ORWELL ROPE STUDY

Problems

1. Reservoir

   A. Summer fluctuations

      a. Fish spawning hindered/fry-fingerling survival impacted
      b. Precludes establishment of aquatic plants and invertabrate populations
      c. Contributes to bank erosion which leads to turbidity and wind erosion problems.

   B. Winter drawdowns

      a. Contribute to bank erosion
      b. Aquatic habitat reduction and potential for winterkill
      c. Destroys littoral zone

   C. Extended high maximum reservoir level

      a. Contributes to bank erosion, increased turbidity, and siltation
      b. Precludes optimum littoral zone production

2. South arm and other shallow extensions of reservoir

   A. Summer fluctuations

      a. Floods waterfowl nests (overwater and upland)
      b. Floods nests of upland game birds (prairie chicken, pheasant and hungarian partridge) and non-game species
      c. Reduces quality of upland habitat
      d. Strands waterfowl broods
      e. Harms furbearer production and survival
      f. Fish spawning and fry/fingerling survival hindered

   B. Winter drawdowns

      a. Freeze out or strand furbearers
      b. Eliminates water important for spring waterfowl courtship activities

   C. High maximum reservoir level

      a. Wetland areas inundated
      b. Precludes establishment of aquatic plants and invertebrate populations
      c. Allows rough fish access from main Reservoir

3. Downstream of Reservoir

   A. High flows

      a. Impacts on fish spawning and fry/fingerling survival
      b. Impacts on available habitat for juveniles and adults
      c. Bank erosion

   B. Low flows

      a. Impacts on fish spawning and fry/fingerling survival
      b. Impacts on available habitat for juveniles and adults

c. Reduces value for aquatic recreation
d. Impacts bank denning furbearers
e. Impacts on invertebrate production

C. Rapid change in discharge

a. Stranding of fish and invertebrates
b. Impacts on fish spawning and fry/fingerling survival
c. Impacts on available habitat for juveniles and adults
d. Impacts on invertebrate production
e. Can contribute to bank erosion

Planning Constraints

1. Flow regime for downstream fisheries (to be determined from instream flow study)
2. Presence of roughfish in reservoir
3. Continued use of reservoir for flood control
4. Maintenance of value of waterfowl sanctuary and wildlife management area
5. Hydrologic constraints (evapotranspiration, inflow to reservoir, operation of upstream structures)

Opportunities

1. Stabilize pool in summer
2. Lower maximum pool level
3. Raise minimum pool level
4. Decrease duration of maximum pool
5. Subimpound sites off of reservoir
6. Stabilize banks (shore and islands)
7. Establish appropriate flow regime
8. Slow down rate of reservoir level fluctuations
9. Minimize rate of change in discharge

END

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